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Understanding Economic and Business Impacts of Street Improvements for Bicycle and Mobility – A Multicity Multiapproach Exploration

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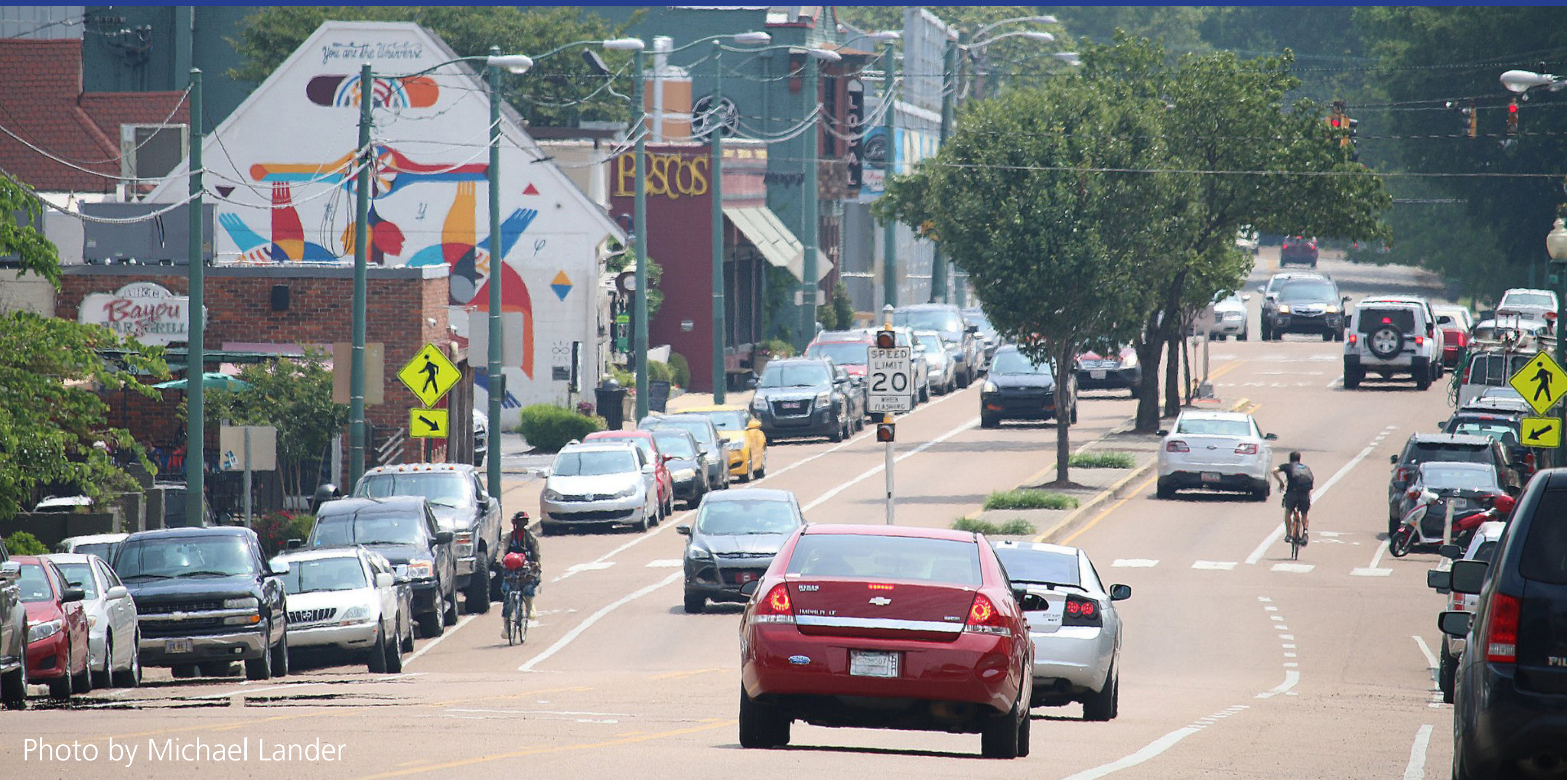

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Understanding Economic and Business Impacts of Street Improvements for Bicycle and Pedestrian Mobility: A Multi-City, Multi-Approach Exploration

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UNDERSTANDING ECONOMIC AND BUSINESS IMPACTS OF STREET IMPROVEMENTS FOR BICYCLE AND PEDESTRIAN MOBILITY: A MULTI-CITY MULTI-APPROACH EXPLORATION

Final Report

NITC-RR-1031-1161

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16. Abstract

Many cities across the country, as part of Complete Streets initiatives or to promote community livability and environmental sustainability, have engaged in street improvement or transportation infrastructure upgrade projects that increase access and mobility for pedestrians and bicyclists through a reduction of on-street parking or traffic lanes. With various transportation modes competing for scarce resources (including right-of-way and transportation funding), city planners and transportation agencies often struggle with how to justify these infrastructure investments for non-motorized modes such as bicycling and walking, particularly when driving is still the predominant mode of transportation in most cities. There is a vital need to understand whether and how these investments impact economic vitality, business activities and neighborhood equity in surrounding areas.

By examining multiple data sources (e.g., Longitudinal Employer-Household Dynamics (LEHD) employment data, Quarterly Census of Employment and Wages (QCEW) employment and wages data, retail sales tax data, and National Establishment Time Series (NETS) employment and sales data), utilizing multiple analytic approaches (e.g., aggregated trend analysis, difference-in-difference (DID), interrupted time series (ITS) analysis, and distributional analysis) on seven corridors within four selected study cities across the U.S. (Portland, San Francisco, Minneapolis, and Memphis), this study aims to accomplish two main objectives:

(i) to establish whether and how these types of investments impact economic vitality, business activities and demographic composition of surrounding neighborhoods with outcomes that are applicable to additional cities and corridors for pre-implementation assessments; and

(ii) to develop a systematic and rigorous methodological approach that is replicable to other cities and corridors for post-implementation evaluation and analysis.

While we observed some mixed results, we generally found that street improvements have either positive impacts on corridor economic and business performance or non-significant impacts. More importantly, this multicity multiapproach exploration allowed the authors to focus on a broader perspective than the individual findings in each corridor or city - detailed comparisons of the different available data sources and methodologies to elucidate the advantages, disadvantages and challenges of conducting research in this field. This study provides policymakers and planners with a solid research and practical foundation as well as a robust analytical framework to strategize the implementation of a multimodal transportation network and to support non-motorized transportation infrastructure investment.

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EXECUTIVE SUMMARY

In response to growing concerns over climate change and rising social inequality, active transportation policy is currently experiencing significant growth in cities across the country, and advocates are arguing for robust bicycle infrastructure. With various transportation modes competing for scarce resources (including right-of-way and transportation funding), city planners and transportation agencies often struggle with how to justify infrastructure investments for non-motorized modes, particularly when driving is still the predominant mode of transportation in most cities. While there are largely positive trends, placing new, robust bicycle infrastructure on major travel thoroughfares still garners intense political backlash in some cities, especially from local business owners who have concerns about revenue reduction because of the installation of new active transportation infrastructure with narrower travel lanes and removing parking.

Although previous studies provide suggestive evidence showing that upgraded active transportation infrastructure can contribute to greater revenue for business establishments through an increase of consumers arriving via an active transportation mode, these studies have largely been descriptive, or exploratory, in nature as opposed to incorporating more rigorous quasi-experimental analysis approaches. This research addresses this technical gap by estimating business and economic impacts of bicycle street improvements using relatively straightforward econometric methods in a quasi-experimental research design. In particular, different data sources were applied, ranging from public employment and sales tax data to proprietary data sources.

Based on the authors' research and collaboration with multiple cities, we analyzed seven street improvement corridors in four cities, Portland, San Francisco, Minneapolis and Memphis (see chapters 5-8 for detailed analysis). Four types of economic data sources were collected for each city if available: Longitudinal Employer-Household Dynamics (LEHD) employment data, Quarterly Census of Employment and Wages (QCEW) employment and wages data, retail sales tax data, and National Establishment Time Series (NETS) employment and sales data. We applied three analytical approaches, aggregated trend analysis, difference-in-difference (DID) and interrupted time series (ITS) analysis, to evaluate the impacts of street improvements on corridor employment and sales.

While we observed some mixed results, we generally found that street improvements have either positive impacts on corridor economic and business performance or non-significant impacts. More importantly, this multicity multiapproach exploration allowed the authors to focus on a broader perspective than the individual findings in each corridor or city-detailed comparisons of the different available data sources and methodologies to elucidate the advantages, disadvantages and challenges of conducting research in this field.

For employment and estimated sales data with the finest geographical scale, NETS and retail sales tax data would be the most appropriate data sources. However, the tradeoff of utilizing NETS data is that the most recently released data only includes information up to 2015, and sales revenue is an estimated number. Retail sales tax data and QCEW data can also provide accurate economic indicator data at very fine geographic detail, but non-aggregated data is typically confidential and researchers and/or practitioners may not be able to access the disaggregated data needed for analysis. The LEHD data source may be the only comprehensive public data source that includes economic indicators at a census-block level. Our analyses additionally showed that the consistency of results varied by data source across the analyzed corridors, which may be due to a number of reasons related to the specifics of each data source: the fuzzy factor applied for confidentiality in the LEHD data, differences in business industry sectors' coverage and details across data sources, and varying geographical detail of each data source (e.g., census-block level in LEHD data versus block-facing level in other data sources). We believe that these differences and tradeoffs underscore the importance of using multiple data sources to validate economic outcomes and trends from street improvements, as well as the importance of understanding the local or regional context when interpreting these quantitative results.

We proposed three different methodological approaches to investigate the economic impacts on street improvement corridors. Aggregated trend analysis and DID analysis both utilize control corridors to understand the impacts on the treatment corridor, while ITS is an econometric technique that analyzes multiple time points on the treatment corridor itself. While the aggregated trend analysis is a visual comparison of differences in trends and growth rates between treatment and control corridors, DID and ITS analyses are quasi-experimental econometric methodologies that allow the researcher to ascertain causality effects of street improvements on business employment and sales. In general, we find that the ITS analysis provides more robust results than the other two methods, since it is a method that does not rely on choosing or finding appropriate control corridors. However, this approach generally requires more data points post-intervention to achieve meaningful and valid impact estimations. For DID analysis, when the control corridors are not perfectly comparable to their treatment counterpart, validity issues in the econometric analysis may arise and lead to biased analytical results.

In summary, this research explored a systematic framework for evaluating the economic development effects of corridor-level bicycle or pedestrian street improvements across a number of corridors in multiple cities. It is our hope that the results of our research will encourage the application of similar corridor selection processes, data collection efforts and multimethod analyses in additional corridors and cities around the country, and will provide a solid basis for policymakers, planners and other stakeholders considering street improvement infrastructure for pedestrian and bicycle mobility to make evidence-based investment decisions.

1.0 INTRODUCTION

In the face of growing concerns over climate change, rising social inequality and what can loosely be described as an emerging urban ethic, active transportation policy is currently experiencing significant growth. In cities across the country, advocates are arguing for robust bicycle infrastructure and expanded public transit. The call for better infrastructure is even more urgent given the rise of bike, and now scooter, share companies that offer people the opportunity to ride and to seriously consider non-auto forms of transport without the commitment of ownership. While these are largely positive trends, placing new, robust bicycle infrastructure on major travel thoroughfares still garners intense political backlash in some cities. In particular, local business owners are often opposed to or have concerns about the installation of new active transportation infrastructure if it requires narrowing travel lanes, or worse, removing parking.

In response, advocates have often claimed that new active transportation infrastructure can be perceived as a type of economic development policy as well as a transportation one. It is often claimed that additional or upgraded infrastructure can contribute to volumes of consumers that arrive via an active transportation mode, and, ultimately, result in greater revenue and employment growth for neighboring business establishments. There is some suggestive evidence of this, ranging from self-reported surveys of business owners (Flusche, 2012; Jaffe, 2015; Stantec Consulting, 2011) to consumer behavior surveys (Clifton et al., 2012; Bent et al., 2009) before and after the installation of active transportation projects. Recently, a few studies have approached this research question by comparing sales tax or employment trends over time on the improved blocks (NYCDOT, 2013; Rowe, 2013; Poirier, 2017). However, while some researchers have started employing quasi-experimental methodologies (Dill et al., 2014; Yu et al., 2018), the majority have been descriptive or exploratory in nature, or have been limited to case studies within specific urban areas. The validity concerns and lack of consistent data backing many of the previous studies have given pause and reason to call for additional research and evidence to address the data and methodological concerns.

This research addresses this technical gap by proposing and exploring a research framework to estimate business and economic impacts of new cycling infrastructure (or bicycle street improvements), based on the authors' research and collaboration with multiple cities using relatively straightforward econometric methods in a quasi-experimental research design. By examining multiple data sources, utilizing multiple longitudinal economic and business activity indicators (e.g., employment by industry sector, number of establishments, business revenues, etc.) and applying distributional analysis and spatially based econometric approaches to seven sets of street improvement corridors (treatment and control) in four study cities across the U.S. (Portland, OR; San Francisco, CA; Minneapolis, MN; and Memphis, TN), this study aims to provide policymakers and planners with a solid research and practical foundation as well as a robust analytical framework to strategize the implementation of a multimodal transportation network and to support non-motorized transportation infrastructure investments.

2.0 LITERATURE REVIEW

Many cities across the country are implementing bicycle and pedestrian infrastructure and related road modifications to tackle a multitude of environmental, public health, and traffic safety concerns. Research has shown that the creation of these types of facilities generally stimulates the local economy by attracting bicyclists, hikers, and other tourists to the area (Flusche, 2012). There is a vital need to understand whether and how these investments impact economic vitality, business activities and neighborhood equity in surrounding areas. The following is a discussion of the literature describing various types of bicycle and pedestrian mobility-focused street improvements, and the impacts of these street improvements on the local economy and businesses.

2.1 TYPES OF STREET IMPROVEMENTS

There are a growing number of studies that examine street improvements, characterized as the introduction of active non-motorized transportation infrastructure, sometimes combined with the reduction of on-street parking or travel lanes. Different types of bicycle facilities have different amenity values depending on whether they are on-street lanes, separated from roadways by physical separations such as curbs or landscaping, or more distant from roadways within open spaces (Krizek, 2006).

Complete streets are one type of classification of road designed to be safe for all road users, including drivers, bicyclists, transit users and pedestrians of all ages. According to Litman (2014), for cities to be more efficient and livable, the transportation systems must promote resource-efficient modes of travel like walking, bicycling and transit. The concept of complete streets focuses not only on individual road facilities, but also on changing the transportation planning decision-making process to ensure that all road users are considered during the road facility investments (LaPlante et al., 2008). Multimodal transportation complete streets address various user needs across multiple modes and provide a wide range of benefits to the community. Some of the common features of complete streets include sidewalks, bike lanes, dedicated bus lanes, median islands and curb extensions. It may also include reducing traffic and parking lanes, traffic calming projects, and improving sidewalks and regulations (Litman, 2014). One of the most important features when designing complete streets is choosing a speed limit that is appropriate for vulnerable road users (pedestrians and bicyclists) and that allows for their safe movement on the streets (Moore et al., 2013; Reynolds et al., 2009; Sanders et al., 2010). Complete streets provide social, economic, health and environmental benefits to communities as well as improvements in traffic performance.

While complete streets typically involve a multimodal focus, the removal of “travel lanes from the roadway and replacing them and utilizing the space for other uses and other modes” (Knapp et al., 2014; McCormick, 2012), or road diets, represent another commonly used technique which may improve bicycle or pedestrian mobility. A traditional road diet involves the conversion of an existing four-lane segment into a three-lane segment consisting of two through lanes and a center, two-way left-turn lane. This change in the road infrastructure reduces the number of conflict points and places where a crash is likely to occur. Road diets are beneficial to non-motorized road users as they reallocate space from travel lanes to new facilities such as bike lanes, sidewalks etc. Another benefit of road diets is the reduction in vehicular speed limits, which leads to a reduction in the number of crashes on the road. However, opponents of road diets argue that reducing auto travel lanes and replacing them with bike lanes can lead to traffic congestion, and, therefore, make it difficult for customers to access businesses (McCormick, 2012).

Bicycle boulevards are another type of street improvement that attract bicyclists, with fewer vehicles on the roads and travelling at reduced speeds. Walker et al. (2009) states that “bicycle boulevards are low-volume and low-speed streets that have been optimized for bicycle travel through treatments such as traffic calming and traffic reduction, signage and pavement markings, and intersection crossing treatment.” There is a strong preference by bicyclists for bicycle boulevards, thereby making them a key tool in attracting new cyclists who feel less comfortable riding in traffic even when bike lanes are provided (Broach et al., 2012; Dill et al., 2014; Walker et al., 2009). Bicycle boulevards allows the development of bikeways along corridors where other types of treatments may not be practical due to right-of-way and funding restrictions (Walker et al., 2009), especially when the design builds upon existing traffic calming features.

2.2 BUSINESS IMPACTS AND ECONOMIC VITALITY

The changes in travel patterns, spending patterns and neighborhood desirability as a result of street improvements for bicycle and/or pedestrian mobility can have an impact on both business activities and economic vitality of the neighborhood (NYCDOT, 2013). Street improvements may also have indirect impacts on the economic vitality of the business district, such as retail and office rentals, property values, and changes in employment in terms of types of jobs or salaries.

Local business owners are often vocal opponents of street improvement projects due to their concerns about losing revenue or customers when street designs involve parking space removal or travel lane reductions. There have been a number of studies that aim to analyze the impacts of street improvements on local businesses. Most are based on individual case studies that utilize business interviews or merchant surveys (Flusche, 2012; Drennen, 2003; Sztabinski, 2009; McCormick, 2012). The lack of data and research that systematically and rigorously analyze the impacts that these bicycle facilities have on retail streets and businesses contribute to these concerns. The majority of businesses believe that a majority of their customers arrive by car, therefore the removal of on-street parking would lead to a decrease in revenues for their business (Drennen, 2003). However, a number of studies have shown that street improvements such as the addition of new bike lanes, complete streets or road diets improve business conditions and raise the revenues for businesses. For example, Sztabinski (2009) showed that efforts to attract more pedestrians and cyclists has a more positive economic impact on businesses compared to maintaining existing on-street parking.

There are a few recent new studies utilizing local business retail sales or employment data before and after the street improvements to study the impacts of street improvements (NYCDOT, 2013; Rowe, 2013; Poirier, 2017). In an archetypal example, New York City DOT, in collaboration with Bennett Midland, developed a methodology to compare retail sales taxes before and after street improvement projects on treatment sites (commercial corridors where new infrastructure is constructed) to control sites (nearby streets with similar conditions) (NYCDOT 2013). The authors found that these street improvements either had no impact or had a positive impact on retail vitality.

Following a similar approach, Rowe (2013) studied the effects of bike lane improvements in Seattle, WA, by collecting retail sales data before and after bike lanes were installed on 65th Street and Greenwood Avenue. The results showed a 400% improvement in retail sales on 65th Street after the bike lane installation compared to the rest of the neighborhood, while sales stayed the same on Greenwood Avenue after the installation of the bike lane. While there are positive results in some cases, it is difficult to attribute these increases solely to the bicycle facility when there may be other economic or external factors that contributed to the changes in growth patterns.

More recently, Poirier (2017) compared before-and-after sales revenue for abutting and non-abutting street improvement corridor business establishments in San Francisco, and found street improvements tended to benefit local-serving businesses instead of all types of business establishments evenly. However, a study in downtown Vancouver, British Columbia found a slight decrease in retail sales after the implementation of separated bike lanes (Stantec Consulting, 2011).

There are other approaches that investigate the economic impact of street improvements by examining the relationship between travel modes and consumer behavior. The general consensus is that increases in the number or length of bicycle facilities leads to increased levels of cycling (Dill et al., 2003; Pucher et al., 2010), and thus increased volume of consumers travelling to nearby businesses. In addition, surveys conducted in Portland, Dublin (Ireland), San Francisco, and New York all have found that bicyclists and pedestrians tend to spend more compared to drivers in commercial areas because bicyclists and pedestrians tend to visit local businesses more frequently compared to drivers (Popovich et al., 2014; Bent et al., 2009; Lee, 2008; Clifton et al., 2012). These studies utilized business owner surveys or intercept consumer surveys to learn about the various travel modes by which they arrived at the establishments and resulting expenditure behavior in local businesses.

A study of 89 businesses in Portland by Clifton et al. (2012) found that drivers spend more per visit (but visit fewer times per month), while bicyclists spent more per capita per month compared to other modes of transport. The study showed that bicyclists tend to spend less on grocery shopping trips, but more at bars/restaurants and convenient stores.

A similar study was conducted in Dublin in which about 1,009 shoppers were surveyed to identify the differences between perceived and actual spending levels by travel mode (O'Connor et al., 2011). The study found that store managers perceived that the majority of their customers arrived by car, and this perception was higher than the actual mode share used by customers. For example, store managers believed that 19% of all customers arrived by car on Henry Street, but only 9% actually arrived by car.

A study by McCormick (2012) surveyed merchants and customers along York Boulevard in Los Angeles, and found similarly that most businesses assumed that their customers arrived by car (60% to 70%), and only 15% to 30% of customers surveyed arrived by car.

Clifton et al. (2012), Connor et al. (2011) and Bent et al. (2009) all show that drivers spend more per visit compared to pedestrians and bicyclists. However, when the monthly spending totals are calculated, bicyclists and pedestrians outspend drivers, contrary to common perceptions of local business owners who believe that the majority of their customers come by car and that drivers spend more money than bicyclists, transit riders and pedestrians.

While these studies provide insights into our understanding of the spending patterns of consumers who utilize different modes of travel, because the data is collected via surveys of either business owners or intercepted consumers, it is difficult to make definitive statements of the overall business or economic impacts of new bicycle or pedestrian infrastructure or to extrapolate these results to other cities or street improvement scenarios. These methodological approaches do not allow for comparisons across existing sites or cities, therefore limiting the applicability of the study results to other cities that may be contemplating similar infrastructure investments or adequate pre- and post-evaluation of street improvement projects.

Based on the existing research and case studies, the question of whether streets improvements that promote bicycle and pedestrian mobility stimulate or impede economic vitality remains largely unanswered. In addition, there is a lack of rigorous and systematic methodology that measures economic and business impacts on a corridor-level geographic scale that can produce consistent, replicable and applicable results.

This research aims to fill in some of these gaps with an approach that includes multiple street improvements across multiple cities, exploring a number of data sources and econometric methodologies to examine the economic and business impacts of street improvements for non-motorized transportation to ensure the robustness of results.

Furthermore, this study will characterize equity and diversity impacts through a distributional analysis of employment opportunities by income levels, education and racial composition within study corridors.

3.0 DATA

Two types of data are required for this sort of economic development evaluation analysis: transportation facility data and economic performance data. Typically, the transportation data needs to be in a GIS (geographic information system) format and include variables that describe the location of the street improvement treatment corridor and corresponding control corridor(s), years of construction, and parking or travel lane removal. Economic performance data must be longitudinal in nature and be available at fine geographic scale as to isolate the specific business activities that occur on the street improvement corridors of interest. In addition, many different economic indicators can represent different types of economic development along the street improvement corridor. For example, sales tax revenue or credit card transaction data can typically capture very short-term economic development impacts, while other economic indicators, such as employment and establishment creation, can reflect longer-term economic impacts.

Table 3-1. Potential Business and Economic Impact Indicators

Data source	Key indicator(s)	Geographical scale	Time scale	Availability
Census LEHD	Number of jobs (by sector, wage, education)	Census block	2002-2014; Annual	Nationwide, public
QCEW	Employment, wage	Establishment	1990-2016; Quarterly	Nationwide, accessible through confidential rules
NETS	Number of jobs, revenue, business type and age	Establishment	1990-2015; Annual	Nationwide, private
Retail Sales Tax	Taxable retail sales	Establishment	Varies	Varies

In particular, we explore the usage of economic indicators that reflect economic vitality and business activities, including indicators of employment, business revenue, wages and sales tax receipts. The following sections further describe these data sources that we utilized: publicly available data sources, such as the LEHD; confidential public data sources obtained via partnerships or agreements with public agencies, such as retail sales tax receipts and QCEW; and a proprietary dataset derived from Dun and Bradstreet archival national establishment data called NETS.

In summary, we have found that there is a lack of free, publicly available data that one can use to measure the business or economic impact of new infrastructure at a fine geographic scale. These limitations become much more apparent when examining the economic development impacts of active transportation infrastructure investments as opposed to transportation infrastructure investments such as highways or fixed guideway public transit systems that are much larger in magnitude. Of the datasets that are publicly available, like the LEHD LODES, their lack of industrial detail limit what may be examined. Proprietary employment datasets do not share those disadvantages but, of course, come at a very high financial cost that most researchers will not be able to afford. Finally, it is important to note that changes in employment may only be weakly tied to consumption patterns and may be more reflective of productivity changes, such as the upskilling of workers, or technological advancement such as replacing servers with computer kiosks. Consumption data bypasses many of the disadvantages of employment data but still requires permission from a regulating authority on data use and often has costly data preparation costs in terms of time. Sales tax data is not collected, or often used, for economic development research purposes so researchers will have to deal with working with parent agencies to prepare the data for analysis.

3.1 CENSUS LONGITUDINAL EMPLOYER - HOUSEHOLD DYNAMICS (LEHD)

The Census Bureau publishes the Longitudinal Household-Dynamics Employment (LEHD) Origin-Destination Employment Series (LODES) datasets, which tracks Workplace Area Characteristics (WAC), Residence Area Characteristics (RAC) and Origin-Destination (OD) for all census blocks annually. It integrates existing data from state-supplied administrative records on workers and employers with existing census, surveys, and other administrative records to create a longitudinal data system on U.S. employment. It provides longitudinal employment data at the two-digit NAICS (North American Industry Classification System) level at the census-block or block-group geography for most of the country between 2002 and 2015. The LEHD dataset is the only free, publicly available dataset that gives researchers the ability to track the fine scale geographic development of employment over time with consistent census geographies. As such, LEHD provides geographically granular detail about America's jobs, workers and local economies, allowing us to examine employment by broad industry sector, wage and educational attainment.

The RAC tracks all U.S. workers by their residence locations, allowing us to examine employment by broad industry sector, wage and educational attainment. A list of demographic categories included in the LEHD dataset is described below. It breaks the earnings/income into three categories: less than $1,250, $1,250-$3,333, and $3,333 and above. However, these income categories are fixed for all years, which may limit the ability of researchers to examine detailed income trajectories over time. In order to simplify description of income characteristics, we define the three categories as low income, middle income, and high income. In terms of race characteristics, there are six categories: white, black and African American, American Indian and Alaska Natives, Asian, Hawaiian and other Pacific Islanders, and two or more races. There are four categories of education attainment: less than high school, high school or equivalent, some college or associate's degree, and bachelor's degree or above. Note that those captured in the RAC dataset are only those residents who have jobs, and does not include all residents.

Table 3-2. LEHD Data Demographic Categories

Demographic	LEHD Definition	Variable Name
Income	Earning less than $1,250	Low income
	Earning $1,250 - $3,333	Middle income
	Earnings $3,333	High income
Race	White	White
	Black and African American	Black
	American Indian & Alaska Natives	American Indian
	Asian	Asian
	Hawaiian & other Pacific Islander	Hawaiian
	Two or more races	Two or more races
Education Attainment (only available for workers age over 30)	Less than high school	Less than high school
	High school or equivalent	High school
	College or associate degree	College

Demographic	LEHD Definition	Variable Name
	Bachelor’s degree or above	Bachelor’s or above
Gender	Female	Female

While incredibly powerful, being confined to only two-digit NAICS means that it is impossible to estimate even moderately detailed industrial change. To answer the research question of whether bicycle-related street improvements impact economic development activities, we are only able to examine the retail sector (NAICS sectors 44-45) and food and accommodations sector (NAICS sector 72). We are unable to separate out employment changes in the accommodations sector, which tends to be an industry sector that is less likely to see large impacts in the short term from street improvements related to bicycle or pedestrian mobility. Moreover, although LEHD data is available at smaller geographical scales, such as the census-block level used in this analysis, the real employment data for each block in the LEHD database is distorted by a “fuzz factor” in order to prevent individual establishment identification (Abowd and McKinney, 2014). While the fuzzing does not harm estimates at larger geographic aggregations such as census tracts, it does mean that we should be careful of relying too heavily on economic indicators at smaller geographic scales. Therefore, the employment data used in this analysis should be seen as an estimate where the exact employment trend is ultimately unknown. Another drawback of using LEHD data is it includes all employment in the census block instead of the block facing the street improvement corridor, which might also blur the result. Hence, analysis based on other data sources is required to further unravel economic impacts that occur on street improvement corridors. Finally, the LODES dataset is lagged, making it difficult to see employment impacts of recent street improvement corridors. At the time of writing, the data has yet to be updated with 2016 figures. While the disadvantages of the LEHD LODES dataset limit its overall usefulness for evaluation projects at particularly small scales, its comprehensive coverage, consistency, convenience and (no) cost make it a good starting point in an evaluation project.

3.2 QUARTERLY CENSUS OF EMPLOYMENT AND WAGES (QCEW) DATASET

Beyond LEHD data, there is the public, but confidential (at establishment levels), QCEW data, also sometimes referred to as ES-202 data. This is an establishment-level dataset resulting from the required submission from establishments participating in the unemployment insurance program. The QCEW program publishes quarterly accounts of wages and employment from all employers covered by state unemployment insurance programs. Establishments are required to provide the number of their employees per quarter, total payroll and taxable wages, and their industrial code (NAICS). These data are collected by the states and submitted to the Bureau of Labor Statistics, which uses it as one source of tracking local employment dynamics across the country. Some states allow for the sharing of the confidential microdata with university researchers and researchers from local governments, but because of its confidential nature, potential researchers generally must demonstrate that their organizations can be trusted to safeguard data and to follow strict guidelines on who has ultimate access, how the data is displayed in final reports and studies, and instructions on destroying the data at the end of the project. The process for gaining access to such data varies by state so analysts should contact their state employment departments and research specific data-sharing agreements. Gaining access to the QCEW data, especially if it is already geocoded, solves many of the problems of the LEHD data. Establishment-level data allows analysts to get as much industrial detail as they need. For example, detailed industry codes can help to distinguish local-serving business, which was found to be more impacted by street improvements (Poirier, 2017), from other types of retail businesses. The dataset is longitudinal, and oftentimes available on an annual or quarterly basis, making it possible to track specific establishments over time in an area if need be.

Some downsides of the QCEW data are that it can be very difficult to gain access, clearly, but researchers must also be aware that because this data is self-reported that establishment industrial codes may change because businesses may decide a former code was no longer accurate, as well as ongoing NAICS code modifications. For example, in the state of Oregon, Nike’s headquarter was previously listed under the set of manufacturing NAICS codes for garment manufacturing, but in the early 2010s changed to the NAICS code representing management of business.

We were able to obtain QCEW for Portland, Minneapolis and Memphis (three out of four cities) for this analysis. The Portland Bureau of Planning and Sustainability was able to provide establishment-level data from 2004 to 2015 after a confidentiality agreement for research purposes was approved by the Oregon Employment Department. While food and accommodations QCEW was not available for Minneapolis, Minnesota’s Department of Employment and Economic Development was able to provide aggregated employment in retail establishments (with NAICS codes 442-453) for our analysis street improvement treatment and control corridors. For Memphis, we obtained establishment-level QCEW data from the Tennessee State Department of Labor & Workforce Development, and were able to aggregate the employment and wages to the corridor-block level and block-facing level for retail and food services industries.

3.3 NATIONAL ESTABLISHMENT TIME SERIES (NETS)

Private, proprietary sources of employment data exist, such as Walls & Associate's NETS. NETS is comprised of 26 annual snapshots of the DUNS Marketing Information file from Dun and Bradstreet, following over 60 million establishments between January 1990 and January 2015. The dataset offers all of the advantages of the confidential QCEW data, but generally goes further back with consistent industrial coding and does not have additional use restrictions on the display of data. However, these advantages of private data sources often come with a hefty price tag that may not be feasible for individual city agencies or individual projects to attain.

This proprietary dataset tracks individual geocoded business establishments since 1990. It includes business name, linkages with business headquarters, years when business was active, industry classification (primarily SIC with NAICS crosswalk), employment, estimated annual sales and relocation information. Therefore, it provides information along the street improvement treatment and control corridors on numbers of establishments, business types (NAICS sectors), business sizes (number of employees), and estimated business sales revenue on an annual basis.

In order to compare the economic indicators from the NETS dataset with other data sources, and to fully take advantage of the granularity available within this dataset, we constructed two types of industry sectors categorizations: **Type I** was constructed to be consistent with establishments included in the LEHD dataset, which contains retail businesses with NAICS code 44-45 and food services businesses with 722 (we exclude businesses within the accommodations industry here); **Type II** was constructed as a subset of Type I, including local retail and food businesses but excluding automobile-focused retail businesses such as large furniture stores and gas stations, and specialty food services such as food service contractors, caterers, and mobile food services.

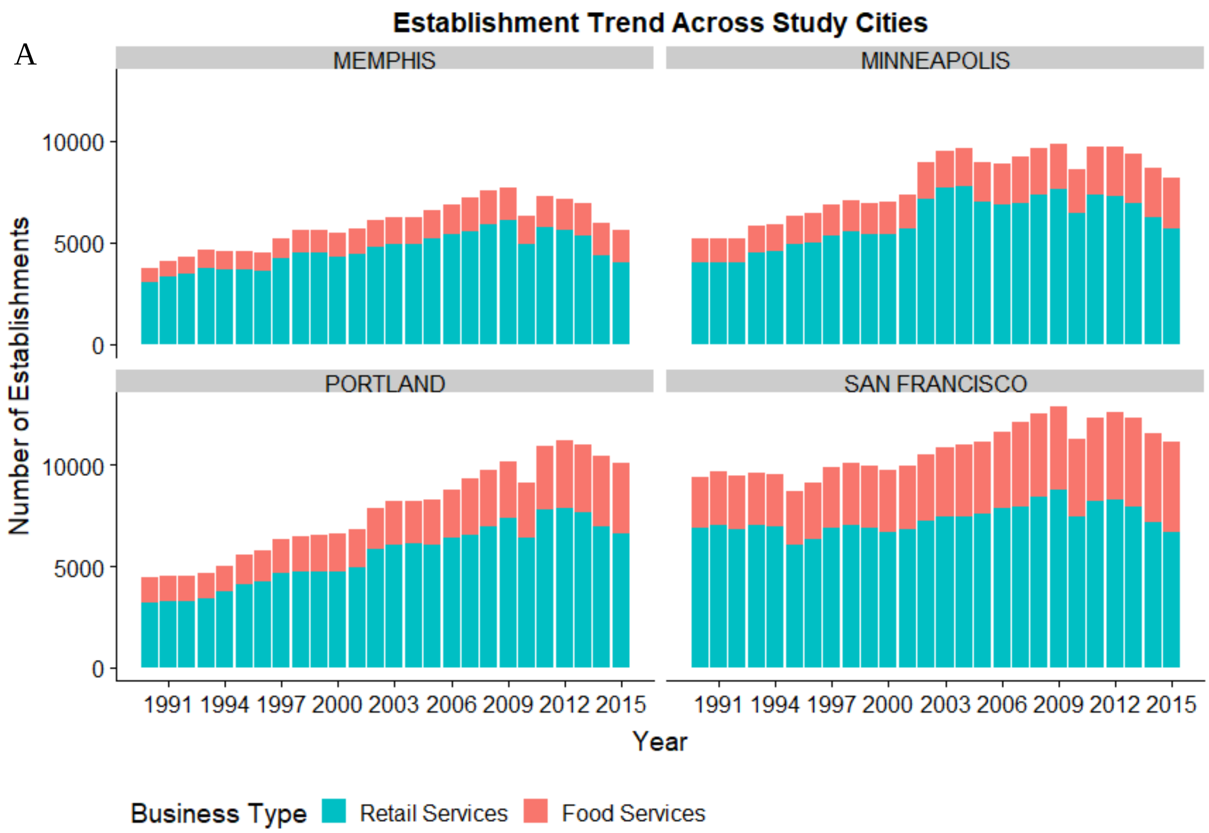
Details regarding which industry sectors are included in Type I and Type II categories are illustrated in the following table. In addition, Type I establishments include establishments located on the entire abutting blocks of the corridors (to be consistent with the LEHD geography), while Type II only includes establishments directly facing the street improvement corridor (block-facing establishments) to more accurately capture impacted businesses.

Table 3-3. NETS Data Industry Type Selection (by NAICS code)

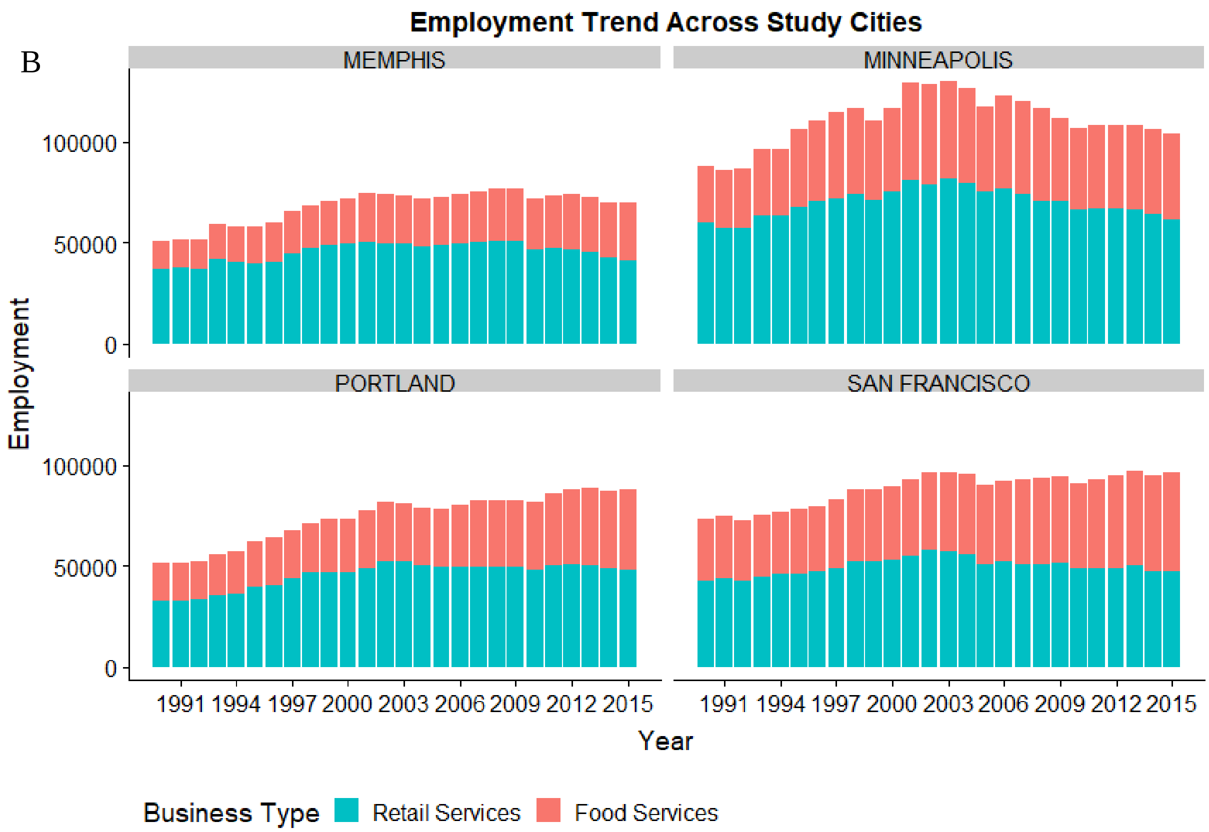
Type I	Type II
Retail Services 44-45: Retail Trade Food Service 722 (includes 7223 Special Food Services; 7224 Drinking places; 7225 Restaurants and other eating places)	Retail Services 4431 Electronics and Appliance Stores 4451 Grocery Stores; 4452 Specialty Food Stores; 4453 Beer, Wine and Liquor Stores; 4461 Health and Personal Care Stores; 4481 Clothing Stores; 4482 Shoe Stores; 4483 Jewelry Luggage and Leather Goods Stores; 4511 Sporting Goods, Hobby and Musical Instrument Stores; 4512 Book Stores and New Dealers; 4522 Department Stores; 4523 General Merchandise Stores; 4531 Florists; 4532 Office Supplies, Stationery and Gift Stores; 4533 Used Merchandise Stores; 4539 Other miscellaneous store retailers 8121 Personal Care Services; 8123 Drying cleaning and laundry services; 8129 Other personal services Food Services 7224 Drinking places; 7225 Restaurants and other eating places;

Additionally, because the NETS dataset includes address information for all business establishments, we are further able to pinpoint whether businesses are directly facing the street improvement corridor. This represents a large improvement over the LEHD LODES (and sometimes QCEW) dataset, which only provide employment numbers for each census block. The following plots illustrate the trends of Type I number of establishments and employment across the four study cities. The number of establishments nearly doubled between 1990 to 2010 and dropped after 2010 (Figure 3-1 A), while employment levels increased more slowly (Figure 3-1 B). In general, the first decade of the 21st century was challenging and economic performance substantially weaker than that of 1990s in most cities. There are apparent drops for all four cities during the 2008 economic recession, but the recessionary effects appear particularly strong in Minneapolis where total employment and retail sales continue to fall after the recession period, while Portland and San Francisco appear to have rebounded in terms of employment and sales volume (Figures 3-1 B and 3-1 C). These figures also illustrate that, while the food services industry sector makes up a smaller share of establishments and sales within the cities analyzed, they account for a relatively large share of number of employees.

A



B



Employment Trend Across Study Cities
MEMPHIS
MINNEAPOLIS
PORTLAND
SAN FRANCISCO
Employment
100000
50000
0
1991 1994 1997 2000 2003 2006 2009 2012 2015
Year
Business Type
Retail Services
Food Services

C

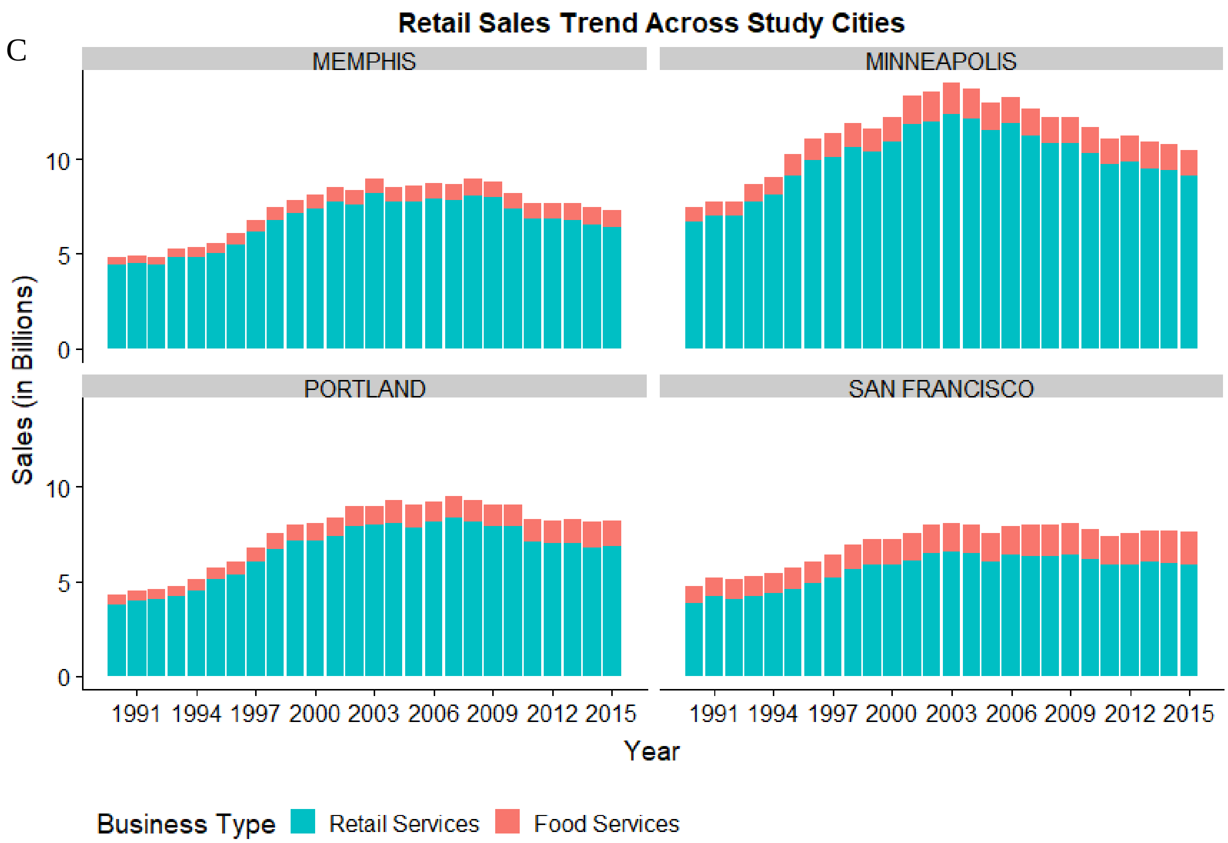
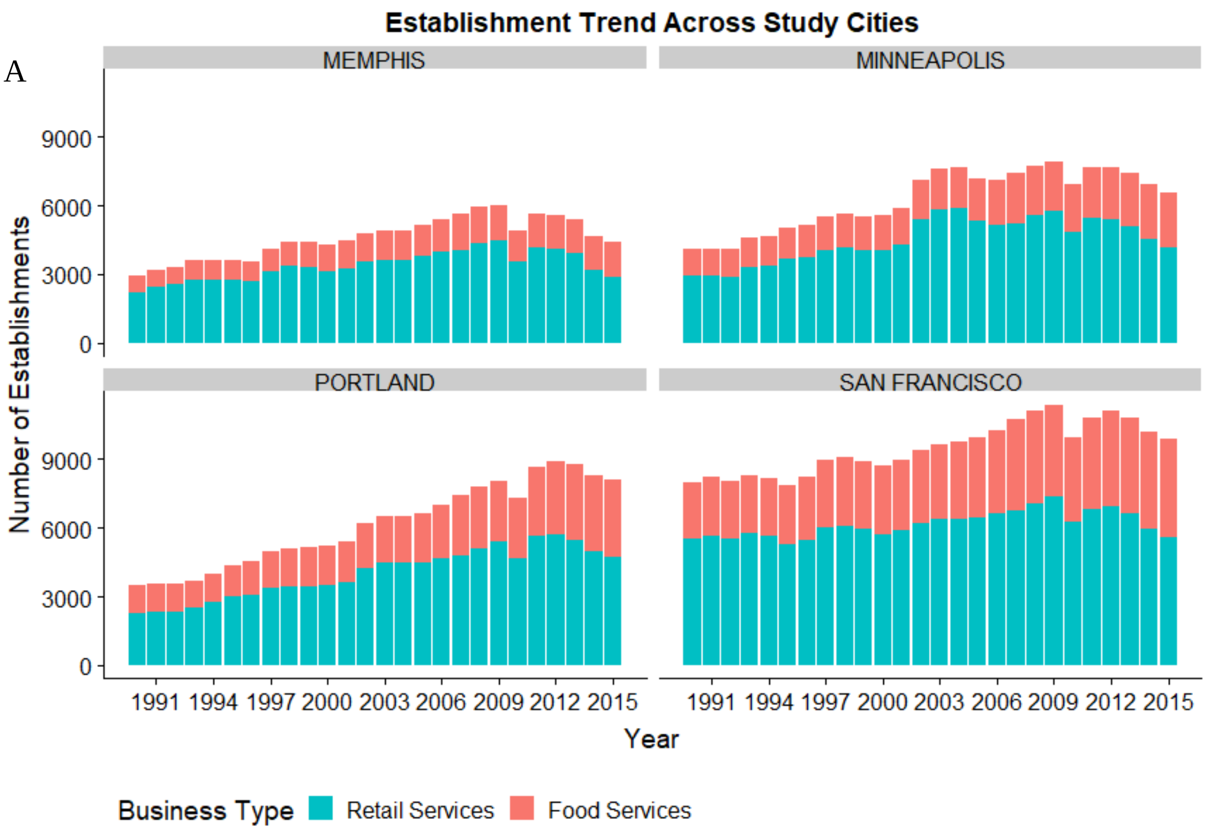


Figure 3-1. Economic Trend of Four Study Cities by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type I

The economic indicators of Type II industries are presented below. In general, they follow a similar trend compared to Type I industries. After excluding non-local serving industries, such as car-related retail stores, we observe that the food services indicators represent an even larger share of the overall retail/food economy. In addition, these types of local-serving businesses appear to be more resilient than Type I businesses. For example, retail sales in Minneapolis and Portland show lesser declines for Type II businesses (Figure 7C) during the recessionary period than compared with the same indicators for Type I businesses.

A



Establishment Trend Across Study Cities
MEMPHIS
MINNEAPOLIS
PORTLAND
SAN FRANCISCO
Number of Establishments
0
3000
6000
9000
1991 1994 1997 2000 2003 2006 2009 2012 2015
Year
Business Type
Retail Services
Food Services

B


Employment Trend Across Study Cities
MEMPHIS
MINNEAPOLIS
PORTLAND
SAN FRANCISCO
Employment
0
30000
60000
90000
1991 1994 1997 2000 2003 2006 2009 2012 2015
Year
Business Type
Retail Services
Food Services

C

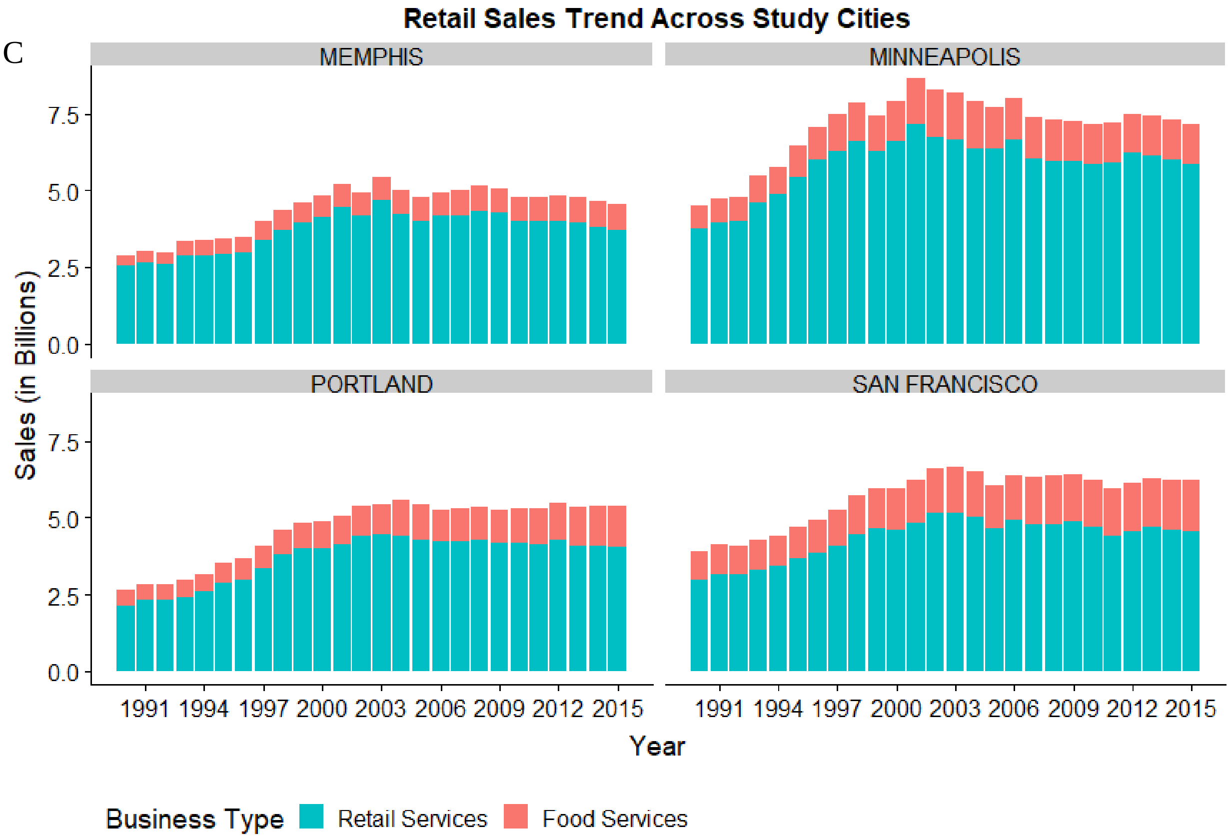


Figure 3-2. Economic Trend of Four Study Cities by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type II

3.4 RETAIL SALES TAX

While many datasets provide employment numbers, employment may not be the most appropriate metric when examining a shorter period of time after the construction of street improvement infrastructure or when we are principally concerned with the effects of new infrastructure on consumption. It may be that the changes in consumption along street improvement corridors are significant, but do not trigger any changes in employment. The options for most researchers seeking consumption data are very limited and consist almost exclusively of sales tax data. Sales tax data has the advantage of being tied to particular establishments, is longitudinal in nature and, most importantly, is a direct measurement of consumption.

Similar to confidential establishment-level QCEW data, analysts must obtain permission from the appropriate office of revenue to gain access. While there are some sources of credit card transaction data available, they are often expensive and include only those sales made with credit cards (and not cash), leaving sales tax data as the most convenient consumption measure in most localities. Retail sales tax usually can be retrieved from city or state departments of revenue, but may not always be available for researchers or in the format that is required for analysis.

While retail sales tax can be a straightforward way to reflect business vitality and economic growth along a corridor, this type of data is not available for cities or states lacking a sales tax, such as Portland. Another disadvantage of sales tax is that sales tax may not be applied to all retail purchases; particularly food, clothing, and professional and medical services may be exempted from sales tax. The sales tax rates in the other three study cities are summarized here:

- Minneapolis sales tax ranges between 8.025% (for example, buying a meal at a restaurant outside of downtown Minneapolis) up to 14.025% (for ordering a meal in a restaurant with live entertainment within the downtown taxing district). The minimal 8.025% rate includes the 6.875% state sales tax, a 0.5% transit tax for Hennepin County (where Minneapolis is located), an additional 0.15% Hennepin County tax and, finally, a 0.5% city sales/use tax. Additional entertainment and accommodations taxes may also be included. However, general clothing, legal drugs and unprepared food are exempted from tax collection, which may hamper the ability of sales tax data to accurately reflect all retail business vitality.

- The sales tax rate for San Francisco is 8.5%, and sales of food for human consumption are generally exempted unless sold in heated condition.

- Tennessee has a general 7% sales tax for all businesses, with an exception on non-restaurant food which is taxed at 5.5%. In Shelby County, where Memphis is located, there is an additional sales tax of 2.25%, as well as an additional 5% accommodations tax. These produce a sales tax range of 7.75-14.25% in the city of Memphis.

4.0 METHODOLOGY

4.1 CORRIDOR SELECTION

Street improvements usually take place along a specific street corridor, and the abutting or street-facing businesses are the entities most directly affected by these infrastructure improvements (Poirier, 2017). Therefore, by focusing on corridor-level economic evaluation, instead of examining specific business entities or examining larger regional economic activities, we aim to capture the most direct impacts of street improvement.

The first step of this research involves selecting street improvement corridors that are located in business districts as treatment corridors, and corresponding control corridors that are similar to treatment corridors except for the street improvement. Generally, this selection process can be either data driven or guided by local experts. The data-driven selection process relies on the availability of high-quality longitudinal data on transportation and economic variables, applying statistical criteria to identify appropriate treatment and corresponding control street improvement corridors. On the other hand, a corridor selection process guided by local experts depends on their knowledge and understanding of regional conditions. While the data-driven corridor selection process may appear to be more robust and less subject to biases, the majority of cities do not currently have this type of active transportation-related dataset readily available. On the other hand, while local experts may possess the best firsthand, on-the-ground knowledge of regional transportation and economic conditions, this approach to corridor selection may reveal personal, ideological or political biases that are unbeknownst to the researcher.

Therefore, we combine these two approaches to corridor selection in our framework by first consulting local planners and experts for potential treatment and control corridor candidates, since they are more familiar with their cities' active transportation projects and local business conditions. These candidate corridors are then evaluated using a data-driven statistical process to ensure that each treatment corridor is appropriate in terms of the type of bicycling street improvement, and also to ensure that appropriate control corridors are matched accordingly.

Different cities may have designed and constructed various types of street improvements, but in order to maintain consistency in the corridors/sites chosen our study approach intentionally includes only those on-street bike lane improvements that were installed in conjunction with removal of parking spots or reduction/narrowing of one or more travel lanes. Ideally, these corridors are made up of a minimum of 10 adjacent blocks with a minimal number of retail-related jobs (i.e., averaging above a certain number of retail jobs per block). Additionally, we chose corridors with improvements installed between 2008 and 2013 in order to guarantee sufficient data (at least three data points pre- and post-treatment) to track pre- and post-treatment economic performance trends. As previous studies suggested, corresponding control corridors with no street improvement but similar in other aspects to each treatment corridor need to be identified as well.

Once corridors are selected based on these criteria, further testing is conducted to discern the level of similarity between treatment and control corridors. We compare similarity in two broad aspects: transportation/geography and business activity levels. In terms of transportation and geographic characteristics, the corridors should ideally be geographically close to each other, with similar street classifications, travel volumes and relative location/role within the city's road network.

Because the corridor selection process is typically conducted prior to requesting sales tax or QCEW data from city agencies or partners, we utilized the publicly available LEHD LODES data as the basis for economic/business indicator comparisons. In particular, we utilize the WAC (Workplace Area Characteristics) dataset to track the employment changes across years in corridor level. The level of business activity in both retail and food services industries should be similar on treatment and control corridors, and the general patterns of growth prior to the street improvement should be similar as well. Furthermore, the ratio of business jobs (defined as the sum of retail and food service industry jobs) to overall number of jobs on the treatment and control corridors should be at similar levels. These similarity tests include quintile comparisons and statistical tests of the corridor employment to citywide employment ratios and average block-level employment on the street improvement corridor and the proposed corresponding control corridors.

Specifically, t-tests are performed on three metrics at the census-block level: (a) "business" employment, the sum of retail and food employment; (b) a census-block level "business share" metric that is the number of business employment over the sum of other services' industry employment such as professional/scientific services, public administration and educational services; alternatively, another business share metric is calculated that includes a smaller share of services' employment (including professional/scientific services, administrative/waste management services and arts/accommodation services). As long as one of the business metrics indicates similarity between the treatment and control corridors, we accept the corridor pair as similar enough for this analysis; and (c) a pre-construction annual employment growth rate.

Table 4-1. Corridor Selection Criteria

Treatment corridor	Comparison corridor - justifying similarity

• Street improvement completion time is three time points before the end time points of the data
• Has sufficient business activities along corridor (i.e., over 70% of the blocks along corridors have business service, such as retail and food service)
	• Same time period with treatment
	• Business activities (t-test):
	  o Sufficient business activities (i.e., % of retail service blocks) or business employment percentile compared with city level
	  o Business density of each block
	  o Economic indicator annual growth
	• Street characteristics (research judgement):
	  o Geography proximity preferred
	  o Similar travel volume/speed limit
	  o Similar location in road network (i.e., arterial passing through or connecting with arterials)

4.2 ECONOMETRICS ANALYSIS

In order to examine the economic impact of street improvement corridors, we conducted spatially based econometric analysis on the street improvement corridors (treatment) and corresponding control corridors using data sources described above to estimate the impacts on economic and business activities across industry sectors. Depending on the availability and suitability of data, we conducted aggregated trend analysis, DID estimations and ITS analysis. The following sections describe each of these approaches in more detail.

4.2.1 Aggregated Trend Analysis

This first method follows the previous NYCDOT study (2013), aiming to examine whether the treatment corridors tend to have better business performance than comparison corridors after street improvements. The approach compares the trends of treatment and control corridors in addition to city-wide trends over the full time period for which we have data. If treatment corridors show greater growth rates in employment or sales tax receipts, or a jump in the level of employment or sales, then that would represent a positive impact of the street improvement on business activities. This method is easy to follow and represents the aggregated trend of business activities.

However, it lacks the rigor of econometric estimates and statistical tests that explicitly test whether or not the street improvement caused the changes.

We examined both absolute and indexed values for all variables. Indexed values are useful when one needs to compare values on different scales. For some corridors the differences in employment or sales tax is large and it is not possible to accurately compare those to smaller corridors without indexing. This is especially important for something like sales tax where some corridors have large amounts of taxable sales due to being on a major travel corridor or having a large anchor retailer like a department store.

4.2.2 Difference-in-Difference (DID)

The second method aims to estimate the difference in business vitality of pre- and post-improvement periods between treatment and control corridors within the same time period. This is known as a difference-in-difference (DID) approach (Angrist et al., 2009). It is a designed to answer the “but for” question of what a corridor’s economic trajectory would look like had the streets not been improved. It requires data from pre/post intervention such as panel data (individual-level data overtime) or cross-sectional data (individual or group level). The approach looks at the change in the variable of interest in the treatment corridor before and after it is treated. In this case, this means looking at some time period before and after a street improvement, and comparing the economic indicators to the control corridor which has not received the street improvement. The difference in growth trajectories between the two periods will give an unbiased estimate of the effect of the treatment.

DID is a useful quasi-experimental technique when true randomized experiments are not possible. This approach removes biases in the second period comparisons between the treatment and control corridors that could be the result of inherent differences between these corridors, as well as biases from comparisons over time in the treatment corridor that could be the result of prior trends. A key assumption of a DID estimate is that the differences between control group and treatment group would have remained constant in the absence of treatment.

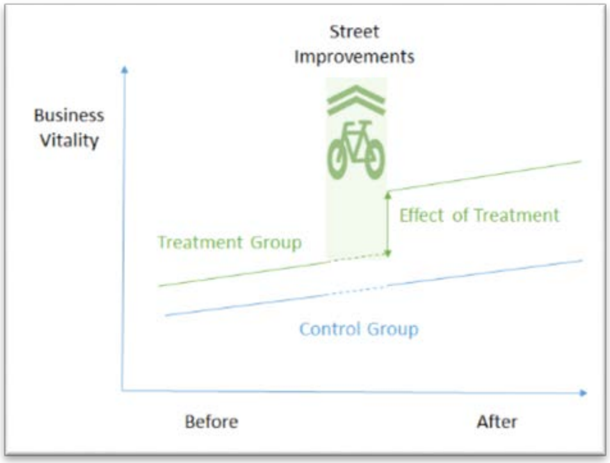


Figure 4-1. Graphical Representation of Difference-in-Difference Estimation

DID is a linear modeling approach and its basic formula is expressed as:

$$Y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 A_{it} + \beta_3 T_{it} A_{it} + \varepsilon_{it}$$

Y_{it} is the observed outcome in corridors i and t (in this case change in employment or sales tax revenue); T_{it} is a dummy variable set to 1 if the observation is from the treatment corridor, or 0 if the observation is from the control corridor; A_{it} is a dummy variable set to 1 if the observation is from the post-treatment period; β_3 is the DID estimator of the treatment effect, specified as the ***prepost:corridor_name*** coefficient in our analysis. Typically, the DID estimator of interest is β_3, and if it is estimated to be statistically significant and positive, then this suggests a positive causal effect of the street improvement on the economic indicator in question. Conversely, if the estimate is significant and negative, then that indicates a negative effect of the improvement. Finally, a non-significant result indicates the improvement had no statistically discernible effect.

Other control variables, such as physical, demographic and built environment dynamics, can be also included as covariates in the model to account for the variation of economic outcomes, and increase the power of statistical tests. Thus, the final formula for a fully specified DID regression would be:

$Y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 A_{it} + \beta_3 T_{it} A_{it} + \beta_4 Cov_{it} + \varepsilon_{it}$

where Cov_{it} is an array of control covariates for treatment group and control group in either time period.

4.2.3 Interrupted Time Series (ITS)

Interrupted time series (ITS) is an econometric technique that estimates how street improvements impact corridor economic vitality from a longitudinal perspective (Gasparrini et al., n.d.). This approach tracks the treatment corridor over time and estimates the impact from the street improvement by identifying changes in its growth trend after the treatment (Lopez Bernal et al., 2016). If the treatment has a causal impact, the post-intervention economic indicators will have a different level or slope than the pre-intervention data points. In our research, ITS will be used to distinguish differences in economic level or growth before and after a specific time period when a street improvement is constructed, such as a new buffered or protected bike lane.

One advantage of ITS is that it allows for the statistical investigation of potential biases in the estimate of the effect of the intervention. Given the longitudinal nature of the test, ITS requires a significantly larger amount of data in order to accurately estimate a real effect on the growth trend.

The interrupted time-series analysis equation can be expressed as:

$$Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 T_t X_t + \varepsilon_{it}$$

Y_t is the observed business outcome in time period t; T_t indicates the number of quarters from start to finish of the series; X_t is the treatment dummy variable taking on values of 0 in the pre-intervention period and 1 in the post-intervention period; β_0 is the model intercept or baseline level at t = 0; β_1 represents the estimated slope (or growth rate) during the pre-intervention period, which we specify as the ***ts_year*** coefficient; β_2 represents the level change following the intervention, specified as the ***prepost*** coefficient; and β_3 indicates the slope change following the intervention, which is the ***ts_year:prepost*** coefficient. A positive and statistically significant β_2 coefficient tends to suggest a positive causal effect on the level of business vitality immediately following the street improvement. A positive and statistically significant β_3 coefficient would suggest a positive causal effect on the growth in business vitality over time.

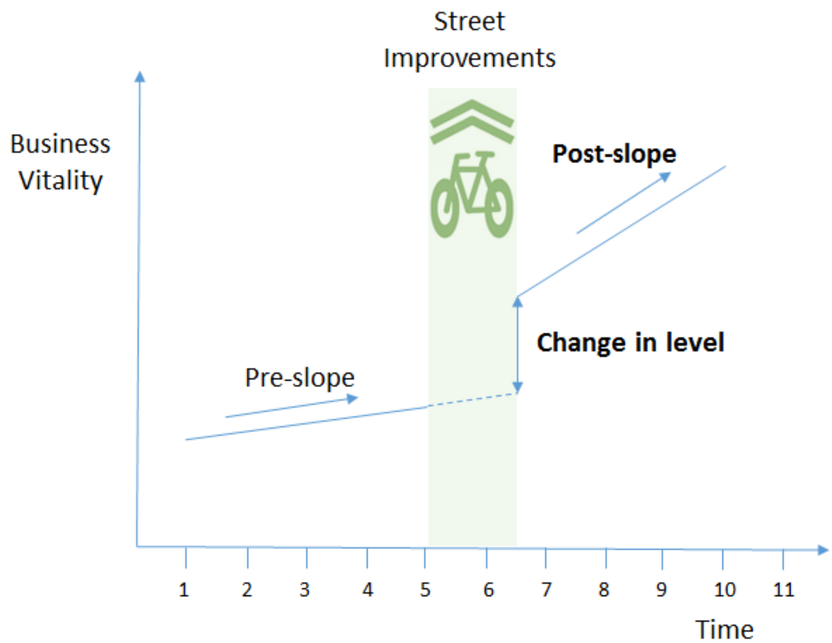


Figure 4-2. Interrupted Time Series Analysis Graph

In conclusion, aggregated trend analysis and DID analysis both utilize control corridors to determine the impacts of the street improvement corridor, while the ITS analysis uses multiple time points on the street improvement corridor itself to pinpoint economic outcomes. In general, the ITS analysis provides more robust results than the other two methods, since it is less likely to be affected by the selection of control corridors. However, this method generally requires more data points post-intervention to achieve meaningful and valid impact estimations. The DID approach is heavily dependent on finding comparable control corridors (which may not always exist), so the analytical results may be weakened when appropriate corridors cannot be identified.

Additional data points after the completion of street improvements may help to provide further validity and rigor to the analysis of resulting economic outcomes. Moreover, further contextual information about the street improvement corridor, such as quality or level of the street improvement, number of parking spots eliminated, and subsequent bicycle ridership or pedestrian increases, would help to better understand the linkages between the improvements and potential impacts on business vitality. Extending this research to more closely examine the changes and shifts in industrial patterns will be valuable as well.

4.3 DISTRIBUTIONAL ANALYSIS

Studies show that those who are the most socioeconomically disadvantaged (i.e., low income, people of color, etc.) are also those who disproportionately experience transportation disadvantages (Lucas, 2012). In addition, these underserved populations tend to have greater demand for transportation access, especially for non-motorized modes of travel (Sandt et al., 2016). The literature on environmental justice emphasizes policies that enable different demographic groups to achieve equitable access to benefits and protection from environmental harm (Rowangould et al., 2016; Schlosberg, 2009; Litman, 2017). Yet, in the context of transportation systems and benefits to transportation infrastructure, minority communities often receive fewer benefits and greater harms when compared with the rest of the population. Commonly used environmental justice indicators include unemployment, household income, elderly residents, children, and ethnic/racial minorities (Foth et al., 2013), and other indicators may include education attainment, zero-vehicle households, limited English proficiency, single-parent households, disability, etc.

To understand the equity and diversity impacts of street improvements, we conduct distributional analysis to characterize the distribution and trend of employment and residential opportunities in treatment/control corridors. The data we utilized for this analysis are the RAC and WAC within the LEHD dataset, where block-level employment demographic information (e.g., racial composition, education attainment, income levels, etc.) is provided. In particular, we compared the trends of environmental justice indicators, such as income/wage levels, educational requirements, and racial and ethnic composition, before and after street improvements for treatment and control corridors. This distributional analysis serves to provide a rough examination of whether there are any significant demographic shifts of residents along street improvement corridors when compared to the trends along corresponding control corridors or within the city as a whole.

5.0 CASE EXPLORATION: PORTLAND

5.1 STARK & OAK CORRIDOR

Portland has completed multiple street improvement projects to improve bicycle ridership levels and safety in recent years. SW Stark Street and Oak Street, our first street improvement corridor, form a couplet in downtown Portland. This treatment corridor consists of approximately 29 blocks in length, where buffered bike lanes were installed in September 2009. As the picture shows, the street improvements involved the conversion of the right travel lane into a wide bike lane separated by a green buffer zone.

Figure 5-1. **Stark St. at 4th Ave.: Street View Before and After Buffered Bike Lane Installation** (Source: Monsere, McNeil & Dill, 2010)

5.1.1 Corridor Selection

There are 67 retail and food service stores along or at the intersecting streets of this corridor distributed across 22 census blocks, which is 76% of all blocks in the corridor. SW Alder Street (including 22 blocks) and NW Everett Street (including 28 blocks) were identified as potential control corridors. We examined the similarity of these two comparison corridors with the Stark and Oak corridor based on similarity of business activity and street characteristics.

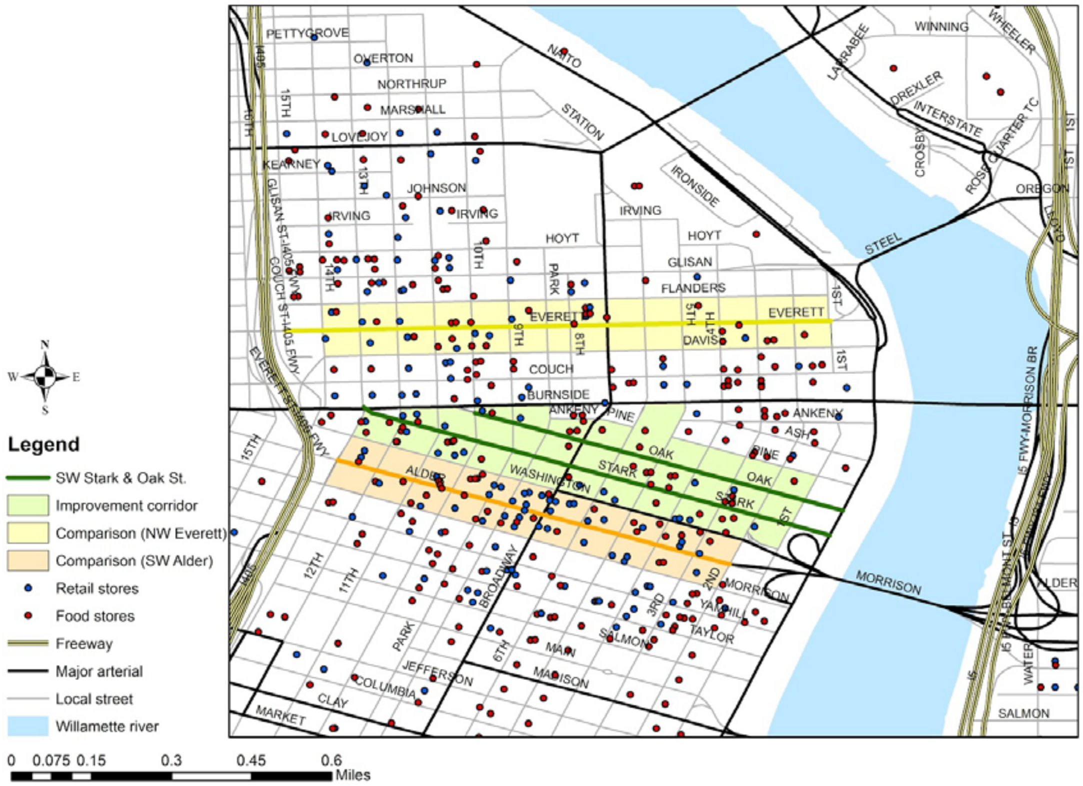


Figure 5-2. Stark & Oak Street Treatment Corridor and Control Corridors

In terms of business activity, all of these corridors are located in downtown Portland with 76% (Stark and Oak), 86% (Alder), and 61% (Everett) of blocks that include retail or food establishments along the corridors. As of 2008, the year before the buffered bike lane was constructed, the business-related (retail and food and accommodation) employment densities per block are 55, 64 and 23 for treatment and comparison corridors, respectively. The treatment corridor has a similar number of retail jobs as the NW Everett corridor, while it has similar food and accommodation jobs with the SW Alder corridor. We further compared their retail employment density percentile with average retail employment density for all blocks within Portland. The treatment corridor is in the 80-85th and 90-95th percentile brackets for retail and food and accommodation jobs compared with Portland's average. The Alder corridor also has a similar number of business jobs (within the same or neighboring percentile brackets), which a similar level of business activity as the treatment corridor. The Everett corridor has slightly less food and accommodation employment than the treatment corridor.

Table 5-1. Comparison of Business Jobs per Block Percentiles among Stark & Oak Corridors

Corridor	Tot Emp.	Retail Emp.	Food Emp.	Tot (%)	Retail (%)	Food (%)
Stark & Oak	332	14	41	95-100	80-85	90-95
Alder	336	27	37	95-100	90-95	95-95
Everett	162	10	13	85-90	75-80	75-80

In addition, we compared the percentage of business jobs in terms of all other service jobs for each block. For the treatment corridor, 39% of all service jobs are business jobs, while the number for the Everett and Alder corridors are 33% and 36%. In addition, the t-test of employment levels indicates that there is no statistical difference between those corridors.

We further compared the business job annual growth rates before improvement completion (i.e., 2002-2009) for the three corridors. The annual growth rate of business jobs along the treatment corridor is 2.3%, while the growth is approximately 2.9% on NW Everett, and -6.4% on SW Alder. Although the t-test indicates no statistical differences (at 95% confidence interval) between the employment levels on the control corridors with the treatment corridor, other indicators show that NW Everett is more similar with our treatment corridor in terms of the pretreatment development trend.

In terms of street characteristics, these are relatively low traffic-volume corridors. However, because SW Alder Avenue connects with the Morrison Bridge to East Portland, it tends to be busier than the Stark and Oak treatment corridor and the NW Everett control corridor. Our examination of the transportation and geographic characteristics indicates that both NW Everett and SW Alder would be appropriate control corridors for the Stark and Oak treatment corridor.

Table 5-2. **Study and Comparison Corridor Selection Criteria (Stark & Oak Corridor)**

Treatment Corridor	**Criteria**		**Control Corridors**	
SW Stark & Oak			NW Everett	SW Alder
• 22 out of 29 blocks (76%) have retail or food stores	Business Activity	Job density percentile	x	✓
		Growth rate	✓	x
• Buffered bike lane • Lane reduction	Street Characteristics	Geography proximity	✓	✓
		Travel volumes/ Speed limit	✓	✓
		Location in road network	✓	x
• Completion in Sept. 2009 • LEHD available in 2004-2015	Time period/ Date	Time	✓	✓
		Data	✓	✓

5.1.2 Economic Outcome Analysis

5.1.2.1 LEHD Data

5.1.2.1.1 Aggregate Trend Analysis

The following table and graph show the employment trends between the treatment corridor and control corridors. Compared to its control corridors and the city as a whole, both retail and food service employment on the Stark and Oak corridor decreased in the year of construction. Rapid growth (or rebound) of retail and food service employment occurs following the street improvement construction, but this trend does not continue in the years that follow. The indexed employment figures below also illustrate that the employment levels in both retail and food services industries on Stark and Oak appear to follow a generally consistent trend of growth with its corresponding control corridors, as well as with the city as a whole.

Table 5-3. Stark & Oak Corridor Aggregated Employment Changes Post-Improvement (LEHD Data)

Corridor	Baseline employment per block (2009)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Stark & Oak	11	41	17.6%	9.9%	-0.6%	-1.6%	6.1%	-1.5%
Everett	3	15	103.2%	-8.4%	18.0%	6.2%	-4.0%	15.0%
Alder	24	51	3.4%	5.2%	4.8%	-12.5%	20.1%	3.6%
Portland	6	7	2.3%	0.6%	0.7%	3.5%	2.5%	3.6%

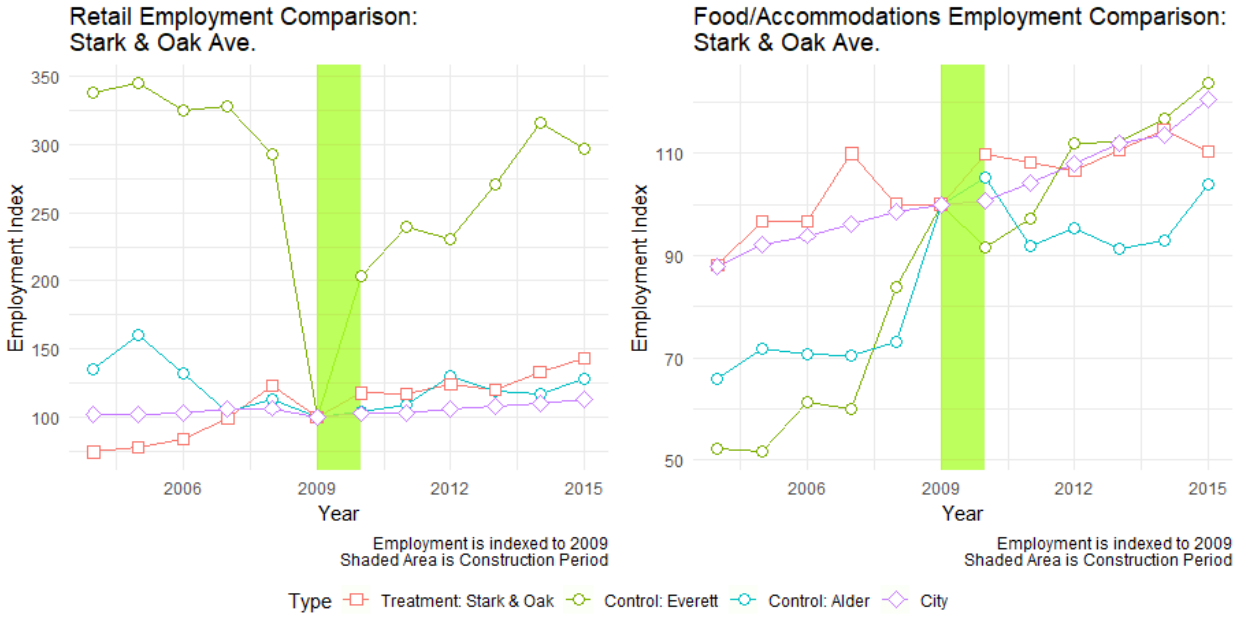


Figure 5-3. Aggregated Employment Trend of Stark & Oak Corridor and Control Corridors (LEHD Data)

5.1.2.1.2 Difference-in-Difference (DID) Analysis

The aggregated trend analysis in the previous section did not show any apparent differences in business activity between the treatment and comparison corridors. While suggestive, this analysis is still primarily a visual check. In order to estimate the economic and business outcomes more rigorously, we applied a DID method to statistically examine the impact of the street improvements. A significantly positive DID effect would indicate positive impact of the treatment (street improvements) on employment growth.

Due to fuzzed employment data at the block level, we used aggregated corridor-level data for the DID analysis. We defined employment before the year of bike lane construction, including construction year, as pre-improvement observations, and the rest as post-improvement observations. The models show there is significant positive impact of the street improvement on retail employment compared to the two control corridors. However, due to the unexpected drop on the Everett control corridor, the effect on overall business employment is unclear. In addition, the impact of bike lane installation is insignificant on food service employment.

Table 5-4. Stark & Oak Corridor DID Regression Results (LEHD Data)

	Dependent variable:		
	Retail Emp.	Food Emp.	'Business' Emp.
Type Control: Alder	362.857***	-467.857***	-105.000
	45.915	62.988	66.427
Type Control: Everett	-137.143***	-1224.286***	-1361.429***
	45.915	62.988	66.427
Pre/post	126.943**	149.000**	275.943***
	50.297	69.008	72.767
DID estimator: Alder	-131.857*	55.275	-76.600
	71.131	97.581	102.909
DID estimator: Everett	-131.857*	16.265	-115.571
	71.131	97.581	102.909
Constant	393.875***	1514.000***	1907.857***
	32.467	44.539	46.971
Observations	36	36	36
R2	0.877	0.957	0.970
Adjusted R2	0.856	0.950	0.965
Residual Std. Error (df = 30)	85.899	117.840	124.274
F Statistic (df = 5; 30)	42.663***	135.024***	193.142***

Note: *p<0.1; **p<0.05; ***p<0.01

5.1.2.1.3 Interrupted Time Series (ITS) Analysis

Finally, we applied an ITS analysis in order to detect any potential longitudinal trends the street improvements had on the treatment corridor. The coefficients represent the effect of the street improvement on job-level change and the growth-rate change. The results indicate that the street improvements did not have a statistically significant impact on retail employment. The estimations show that there is a significant bump in the level of food service employment along the Stark and Oak street improvement corridor, but the effect is insignificant in terms of its growth rate.

Table 5-5. **Stark & Oak Corridor Interrupted Time Series Analysis Results (LEHD Data)**

	Dependent variable:		
	Retail Emp.	Food Emp.	'Business' Emp.
Yearly trend	31.286***	40.464***	71.750***
	6.798	13.534	15.219
Level change	-3.914	123.857**	119.943
	118.839	236.591	266.051
Slope change	-5.686	-21.764	-27.450
	13.252	26.382	29.667
Constant	268.714***	1352.143***	1,620.857***
	30.402	-60.525	68.062
Observations	12	12	12
R^2	0.887	0.736	0.881
Adjusted R^2	0.844	0.636	0.837
Residual Std. Error (df = 8)	35.972	71.614	80.532
F Statistic (df = 3; 8)	20.856***	7.416***	19.832***

Note: *p<0.1; **p<0.05; ***p<0.01

In summary, applying the above three methodologies on LEHD data leads to the conclusion that the SW Stark and Oak buffered bike lane improvement did not have a significant effect on business activities within the retail sector, but did contribute to an increased level of food service employment.

5.1.2.2 QCEW Data

Establishment-level QCEW data was gathered and aggregated at the block-face level to pinpoint retail and food service businesses directly facing the street improvement corridor on Stark and Oak. All NAICS code 44-45 businesses are included in the retail sector, while only NAICS 722 is included for the food service sector (the accommodations industry is excluded from this analysis).

5.1.2.2.1 Aggregated Trend Analysis

The trend of retail and food employment in the treatment corridor is similar to the trends we observed from the LEHD data. There were substantial increases in both the retail and food sectors in the year right after the bike lane installation, possibly due to a recovery or rebound from the construction period. Compared to its control corridors and the city as a whole, retail employment along the Stark and Oak corridor showed continuous growth during the three years following bike lane installation. On the other hand, food employment decreased somewhat after a large spike in 2010.

Table 5-6. Stark & Oak Corridor Aggregated Employment Changes Post-Improvement (QCEW Data)

Corridor	Baseline employment per block (2009)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Stark & Oak	5	25	30.8%	23.1%	15.4%	-5.9%	13.1%	1.5%
Everett	4	16	-23.3%	13.7%	3.9%	-3.3%	16.1%	-2.4%
Alder	22	22	1.0%	-24.5%	-0.3%	-12.5%	-0.3%	-12.5%
Portland	6	7	2.3%	0.6%	0.7%	3.5%	2.5%	3.6%

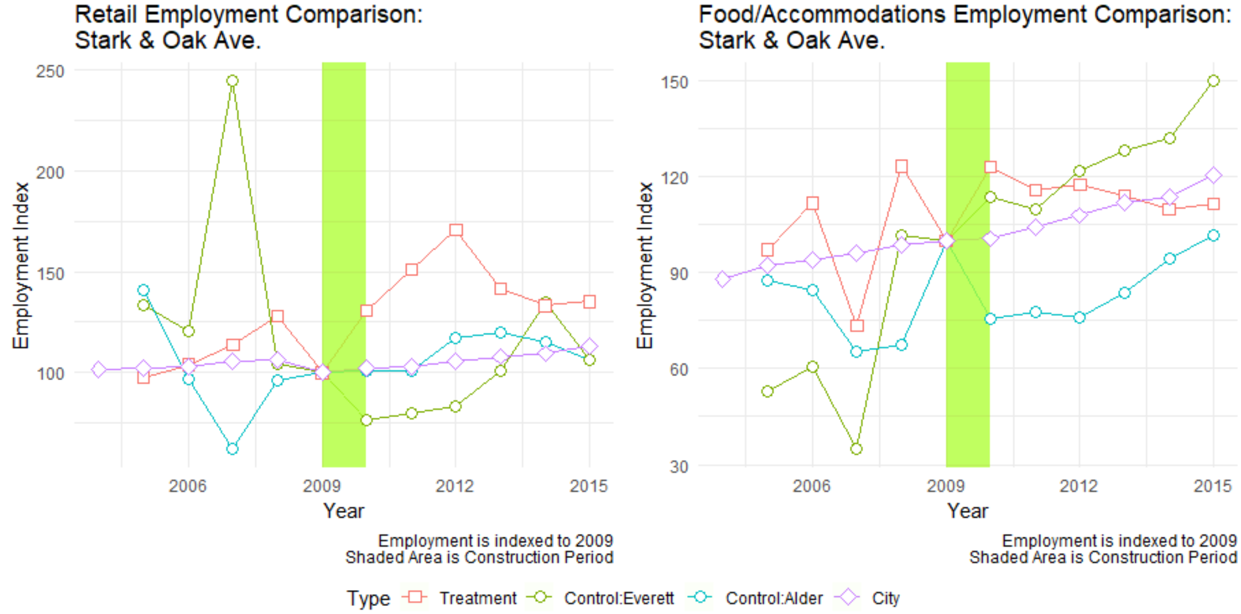


Figure 5-4. Aggregated Employment Trend of Stark & Oak Corridor and Control Corridors (QCEW Data)

5.1.2.2.2 Difference-in-Difference (DID) Analysis

Similarly, DID models were estimated to investigate the impact of bike lane installation on retail and food service employment using QCEW data. The results show no significant impact of bike lane installation on either retail service or food service employment. This is similar to the analysis results of LEHD data.

Table 5-7. Stark & Oak Corridor DID Regression Results (QCEW Data)

	Dependent variable:		
	Retail Emp.	Food Emp.	'Business' Emp.
Type Control: Alder	363.917***	-517.833***	-153.917*
	41.168	62.896	76.465
Type Control: Everett	-59.889	-636.903***	-696.792***
	41.168	62.896	76.465
Pre/post	60.019	84.233	144.253*
	43.177	65.966	80.197
DID estimator: Alder	9.650	-45.917	-36.267
	61.062	93.290	113.415
DID estimator: Everett	-90.861	141.569	50.708
	61.062	93.290	113.415
Constant	198.431***	977.250***	1,175.681***
	29.110	44.474	113.415
Observations	33	33	33
R^2	0.909	0.884	0.859
Adjusted R^2	0.892	0.862	0.833
Residual Std. Error (df = 27)	71.305	108.939	132.440
F Statistic (df = 5; 27)	53.843***	40.997***	32.976***

Note: *p<0.1; **p<0.05; ***p<0.01

5.1.2.2.3 Interrupted Time Series Analysis

ITS models of QCEW were estimated, and indicate there is a substantial increase in retail employment after bike lane installation, but slightly slower growth than before. However, the effects on food service employment is again insignificant.

Table 5-8. Stark & Oak Corridor Interrupted Time Series Analysis Results (QCEW Data)

	Dependent variable:		
	Retail Emp.	Food Emp.	'Business' Emp.
Yearly trend	8.507	38.448	46.955
	5.248	32.772	34.816
Level change	219.968**	407.998	627.966
	74.529	465.395	494.417
Slope change	-20.674***	-53.523	-74.196
	8.703	54.346	57.735
Constant	160.148***	804.236***	964.384***
	25.260	157.738	167.574
Observations	11	11	11
R^2	0.788	0.265	0.409
Adjusted R^2	0.698	-0.050	0.156
Residual Std. Error (df = 8)	21.955	137.096	145.645
F Statistic (df = 3; 8)	8.694***	0.842	1.615

Note: *p<0.1; **p<0.05; ***p<0.01

After analyzing the QCEW using three methodological approaches, we can draw some slightly different conclusions than the analysis of LEHD data. The buffered bike lane installation on the Stark and Oak corridor has a robust positive impact on retail service employment, but no particular patterns of impacts on food service employment. We believe that these differences can be attributed to differences in geographical scales of the LEHD and QCEW datasets - LEHD data includes all employment on a census-block level (and may be fuzzed for confidentiality), while QCEW data includes employment on the blocks facing the street improvements with much more accuracy.

5.1.2.3 NETS Data

5.1.2.3.1 Aggregated Trend Analysis

Using NETS data, the following tables and figures summarize the employment and sales revenue changes before and after the street improvement on the Stark and Oak treatment corridor, the corresponding control corridors and at the city level. Economic data from two types of industry categories are presented: Type I industries include all establishments in the abutting blocks of the corridor, and Type II industries include a more detailed selection of retail and food sector establishments directly facing the corridor, or block-face establishments. Since the treatment and control corridors are neighboring streets parallel to each other in this particular case, there might be overlapping establishments at type I block-level data. In addition, the overall trend plots of each economic indicator are likely to be affected by single large store openings or closures. For example, a single store with very high employment along Stark and Oak corridor closed in 2013, leading to a significant drop in retail employment in 2013 (Figure 5-5A).

In terms of Type I establishments (which correspond most closely with the LEHD data), the treatment corridor experienced a significant drop in retail employment in the year of construction and the following year, but also experienced considerable recovery in retail employment two years following construction, performing better than both control corridors and the city average. However, food service employment on the Stark and Oak treatment corridor continued to decline after the street improvement, while control corridors performed better than the treatment corridor. This trend is particularly obvious in the indexed employment plot (Figure 5-3C). The opposing employment trends in the retail and food service industries may be the result of a shift from food service towards more retail along the improvement corridor.

There is a big difference between retail employment and retail sales after the year of bike lane installation: although the employment dropped, but sales increased sharply during that year. According to the retail sales per establishment plot (Figure 5-4 B), the increase of retail sales is very likely due to the increase of sales per establishment. The reason for this change might be a change in the type of store, switching from stores that require more workers to ones that generate more sales with less employment. Other than this spike in retail sales, the sales in other years generally followed a similar trend as employment, although with some differences in yearly growth rate.

Table 5-9. Stark & Oak Corridor Aggregated Employment Changes Post-Improvement (NETS Data, industry type I)

Corridor	Baseline employment per block (2009)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Stark & Oak	13	25	-7.96%	-3.29%	6.78%	-5.78%	0.22%	-1.08%
Alder	44	22	-2.43%	-15.06%	-10.62%	19.17%	-10.38%	2.94%
Everett	6	12	-19.65%	1.25%	-2.87%	4.32%	2.22%	6.21%
Portland	7	5	-2.18%	0.34%	3.61%	8.32%	1.48%	3.69%

Table 5-10. Stark & Oak Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, industry type I)

Corridor	Baseline sales per block (2009)		Sales change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Stark & Oak	1,423,613	877,003	28.08%	-3.99%	-6.84%	-12.17%	0.05%	2.42%
Alder	5,210,062	809,965	-3.87%	-20.31%	-18.99%	14.95%	-8.06%	3.04%
Everett	694,697	389,623	-15.29%	2.21%	-11.75%	5.50%	-1.38%	6.60%
Portland	1,106,877	158,331	0.03%	0.81%	-10.79%	6.21%	-0.84%	3.37%

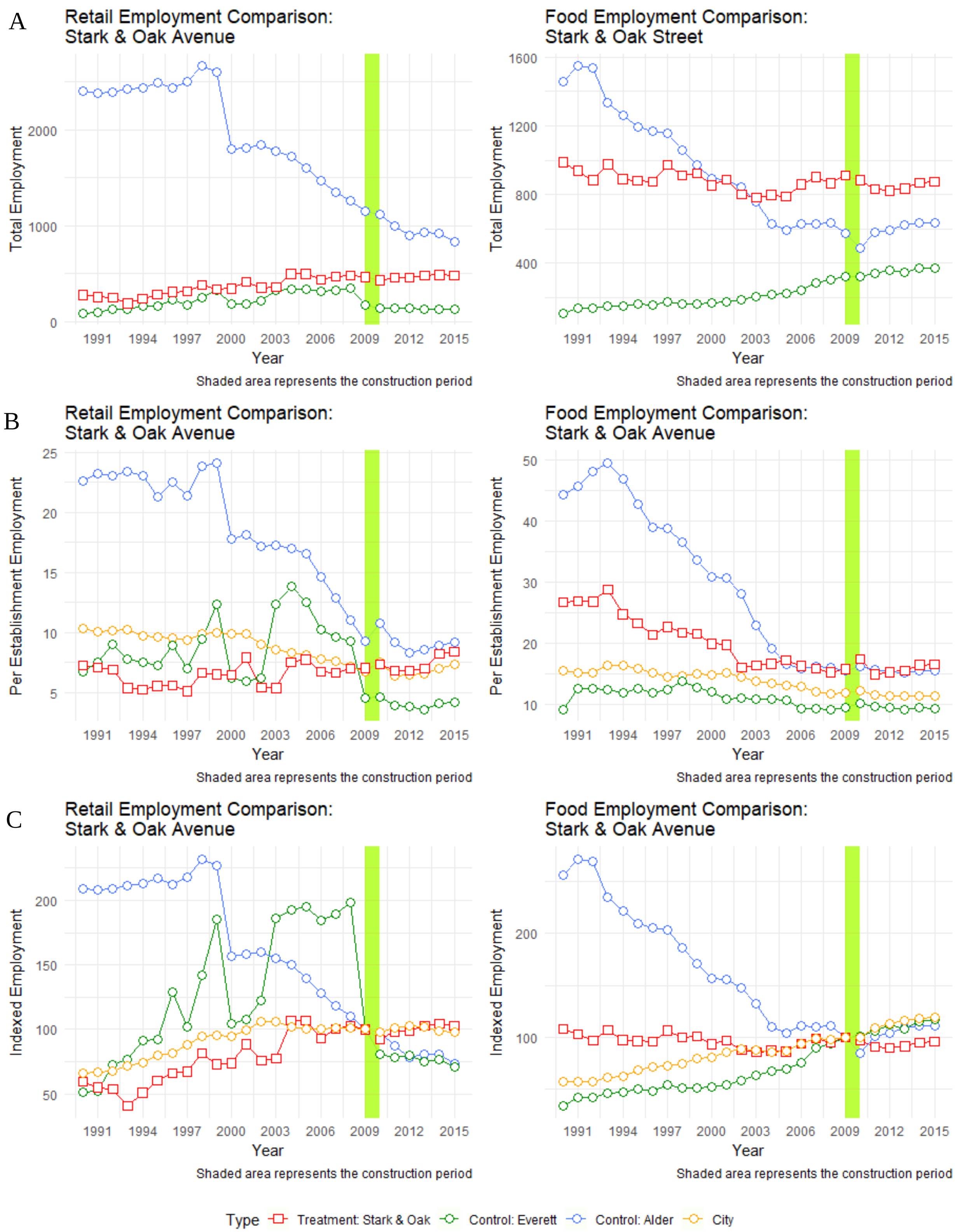


Figure 5-5. Aggregated Employment Trend of Stark & Oak Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type I

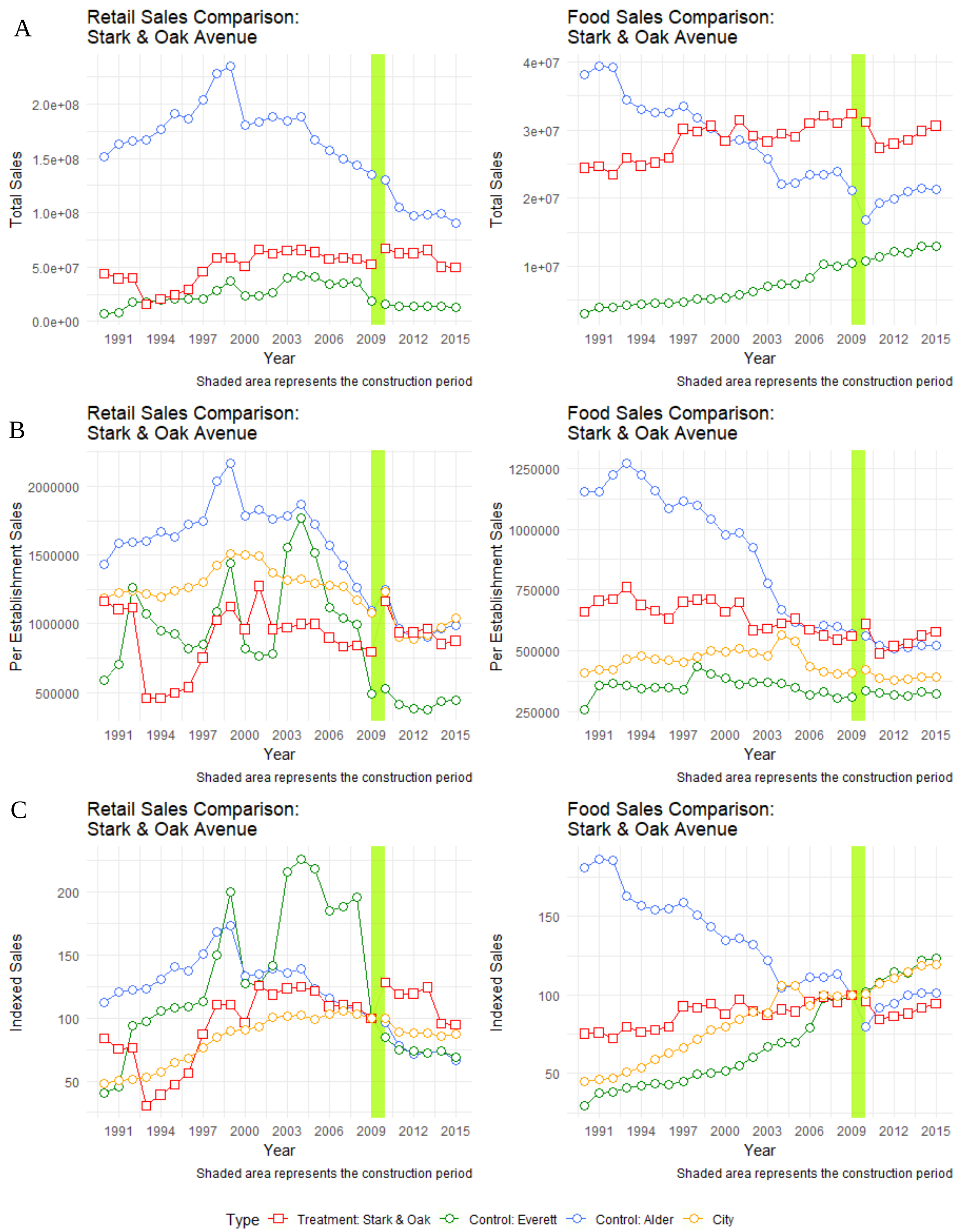


Figure 5-6. Aggregated Retail Sales Trend of Stark & Oak Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type I

In terms of Type II block-face-level establishments' employment trend, it generally follows a similar trend as the block-level Type I employment trend. The NETS data showed that the treatment corridor had a similar amount of retail service employment as the control corridors, but much more food service employment than the other two corridors. However, taking into account the number of establishments, the per establishment employment or sales are similar among all of the corridors. The indexed employment/sales plots are still the key reference to show the economic impacts of street improvements, indicating that the treatment corridor generally performed better economically than the control corridors in retail sector employment and food service employment (Figure 5-7 C). Figure 5-8 presents the retail sales trend, which generally follows the same pattern as employment.

Table 5-11. Stark & Oak Corridor Aggregated Employment Changes Post-Improvement (NETS Data, industry type II)

Corridor	Baseline employment per block (2009)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Stark & Oak	2	10	-14.63%	-1.31%	27.14%	4.27%	2.24%	-1.28%
Alder	4	3	2.67%	5.88%	0.87%	69.44%	3.51%	7.38%
Everett	2	3	-14.55%	3.70%	2.12%	10.71%	-2.08%	8.60%
Portland	6	5	-2.18%	-2.45%	0.37%	8.66%	3.03%	3.70%

Table 5-12. Stark & Oak Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, industry type II)

Corridor	Baseline sales per block (2009)		Sales change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Stark / Oak	195,954	287,024	-[illegible]	-2.57%	36.27%	13.74%	2.20%	3.15%
Alder	620,250	85,312	2.89%	5.59%	-4.84%	63.68%	4.13%	7.87%
Everett	243,848	103,415	-[illegible]	3.81%	-[illegible]	8.39%	-[illegible]	4.88%
Portland	583,403	152,701	0.49%	0.93%	-1.39%	6.72%	3.15%	3.32%

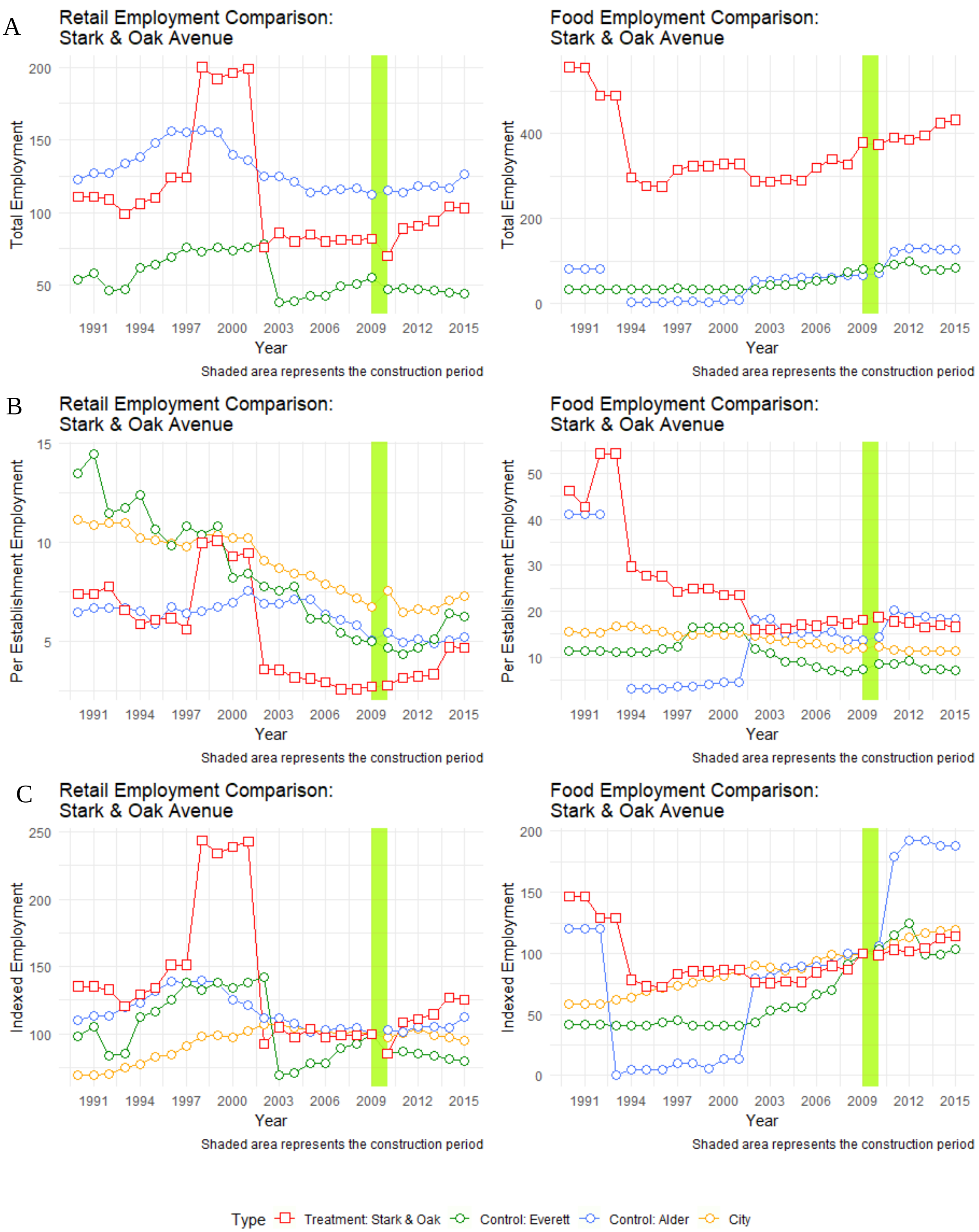


Figure 5-7. Aggregated Employment Trend of Stark & Oak Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type II

Figure 5-8. Aggregated Retail Sales Trend of Stark & Oak Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type II

5.1.2.3.2 Difference-in-Difference Analysis

We further applied an econometric DID estimation to examine the impact on retail employment, food service employment and the combination of the two (i.e., ‘Business’), using the NETS Type II block-face establishment data between 2003 and 2015 to more accurately reflect the economic impacts of the street improvement installation. A significant negative DID estimator of the control corridor would indicate a positive impact of the street improvement treatment on employment. We find that the street improvement has positive significant impacts on retail employment on Stark and Oak when compared to both control corridors, and also a positive significant impact on food service employment when compared to the Everett control corridor. In terms of retail sales, food sales and overall sales, the analysis shows consistent positive, significant impacts of the street improvement on the Stark and Oak corridor.

Table 5-13. Stark & Oak Corridor DID Regression Results (NETS Data)

	Dependent variable:					
	Employment			Sales		
	Retail	Food	Business	Retail	Food	Business
Type Control: Alder	35.857***	-267.286***	-267.286***	8,856,994.000***	-7,455,714.000***	1,401,280.000***
	(2.464)	(10.496)	(10.496)	(234,803.300)	(347,222.400)	(451,347.200)
Type Control: Everett	-33.143***	-269.000***	-269.000***	-884,757.100***	-7,364,486.000***	-8,249,243.000***
	(2.464)	(10.496)	(10.496)	(234,803.300)	(347,222.400)	(451,347.200)
Pre/post	16.343***	73.743***	73.743***	1,516,743.000***	3,481,220.000***	4,997,963.000***
	(2.700)	(11.498)	(11.498)	(257,214.100)	(380,363.100)	(494,426.100)
DID estimator: Alder	-13.457***	-10.314	-10.314	-1,906,494.000***	-1,544,726.000***	-3,451,220.000***
	(3.818)	(16.261)	(16.261)	(363,755.700)	(537,914.600)	(699,224.100)
DID estimator: Everett	-17.057***	-49.000***	-49.000***	-3,304,563.000***	-2,717,714.000***	-6,022,277.000***
	(3.818)	(16.261)	(16.261)	(363,755.700)	(537,914.600)	(699,224.100)
Constant	79.857***	331.857***	331.857***	7,033,557.000***	9,566,100.000***	16,599,657.000***

	(1.743)	(7.422)	(7.422)	(166,031.000)	(245,523.300)	(319,150.700)
Observations	36	36	36	36	36	36
R^2	0.980	0.983	0.983	0.992	0.979	0.979
Adjusted R^2	0.976	0.980	0.980	0.991	0.976	0.976
Residual Std. Error (df = 30)	4.611	19.637	19.637	439,276.700	649,593.600	844,393.300
F Statistic (df = 5; 30)	290.032***	342.708***	342.708***	749.696***	284.285***	282.107***
Note:	*p<0.1;* ***p<0.05;*** p<0.01					

5.1.2.3.3 Interrupted Time Series (ITS) Analysis

The ITS models of the NETS data also indicate that the street improvement on the Stark and Oak improvement corridor has a significant positive impact on retail employment. However, the ITS estimation showed insignificant results for food service employment and overall business employment.

Table 5-14. Stark & Oak Corridor ITS Regression Results (NETS Data)

	Dependent variable:					
	Employment			Sales		
	Retail	Food	Business	Retail	Food	Business
Yearly trend	-1.250***	15.429***	15.429***	-101,403.100	-145,593.100**	-246,996.200
	(0.700)	(2.306)	(2.306)	(389,907.300)	(53,422.230)	(382,047.200)
Level change	-29.657**	11.457	11.457	-8,029,202.000	-4,856,520.000	-12,885,722.000
	(12.240)	(40.315)	(40.315)	(34,654,991.000)	(4,748,171.000)	(33,956,384.000)
Slope change	5.350***	-3.029	-3.029	285,253.100	962,683.100*	1,247,936.000
	(1.365)	(4.496)	(4.496)	(3,443,568.000)	(471,812.300)	(3,374,150.000)
Constant	84.857***	270.143***	270.143***	14,741,002.000***	9,732,940.000***	24,473,942.000***
	(3.131)	(10.313)	(10.313)	(2,634,881.000)	(361,012.000)	(2,581,765.000)
Observations	12	12	12	26	26	26
R^2	0.900	0.953	0.953	0.065	0.539	0.043
Adjusted R^2	0.863	0.935	0.935	-0.063	0.476	-0.088
Residual Std. Error	3.705 (df = 8)	12.203 (df = 8)	12.203 (df = 8)	10,819,489.000 (df = 22)	1,482,407.000 (df = 22)	10,601,380.000 (df = 22)
F Statistic	24.063*** (df = 3; 8)	53.865*** (df = 3; 8)	53.865*** (df = 3; 8)	0.509 (df = 3; 22)	8.561*** (df = 3; 22)	0.326 (df = 3; 22)
Note:	*p<0.1;* ***p<0.05;*** p<0.01					

5.1.3 Distributional Analysis

The distributional analysis aims to track the demographic changes of residents along the treatment corridor, control corridors, and the city as a whole before and after the bike lane installation to examine any potential equity outcomes of the bike lane installation on the Stark and Oak corridor. This analysis is conducted using the LEHD dataset, where income indicators are available for a longer time period (covering both the pre- and post-construction periods), while gender, race and education indicators are only available starting in 2009.

5.1.3.1 Income

All three corridors examined experienced drops in low-income employment, especially after 2008. However, as the income variable is not indexed by inflation, the drop in low-income employment might be due to economic growth in general. The treatment corridor had a significant increase in high-income employment compared to the control corridors after bike lane installation.

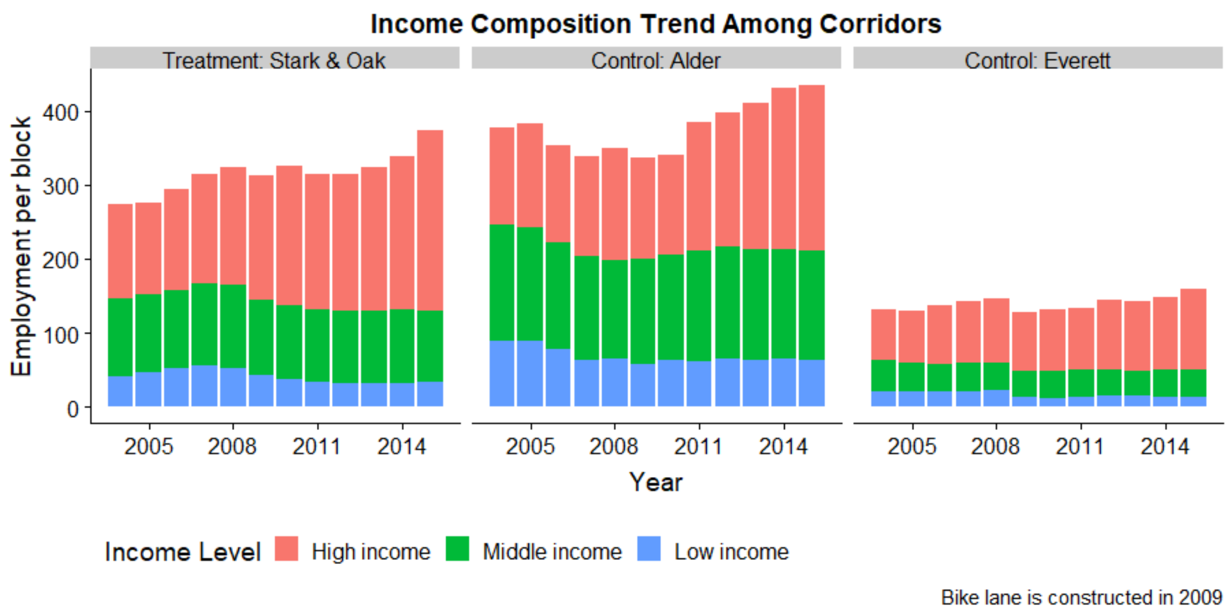


Figure 5-9. Stark & Oak Street Income Composition Trend Among Corridors

5.1.3.2 Race

5.1.3.2.1 Employment

In terms of racial composition of employment along these corridors, the percentage of white employment has decreased while the percentage of black, Asian, and other employment has increased gradually. These trends follow the overall city trend in terms of employment racial composition, with small gains in racial diversity over the examined years. However, overall white employment in Portland remains at a much higher percentage than any other race (86%). We do not observe any divergent pattern in the racial composition of employment along the street improvement corridor when compared with the control corridors or the city.

Due to the fuzzy factor applied in LEHD data, there are some unexpected fluctuations in the annual trends. Table 5-15 summarizes the percentage change of employment racial composition. One thing to notice is that, due to the lower number of some groups, the percentage change may look very large even when the actual employment changes are small. The table below shows similar results as the graph, that the race composition trend in the treatment corridor is similar to the city trend and two control corridors.

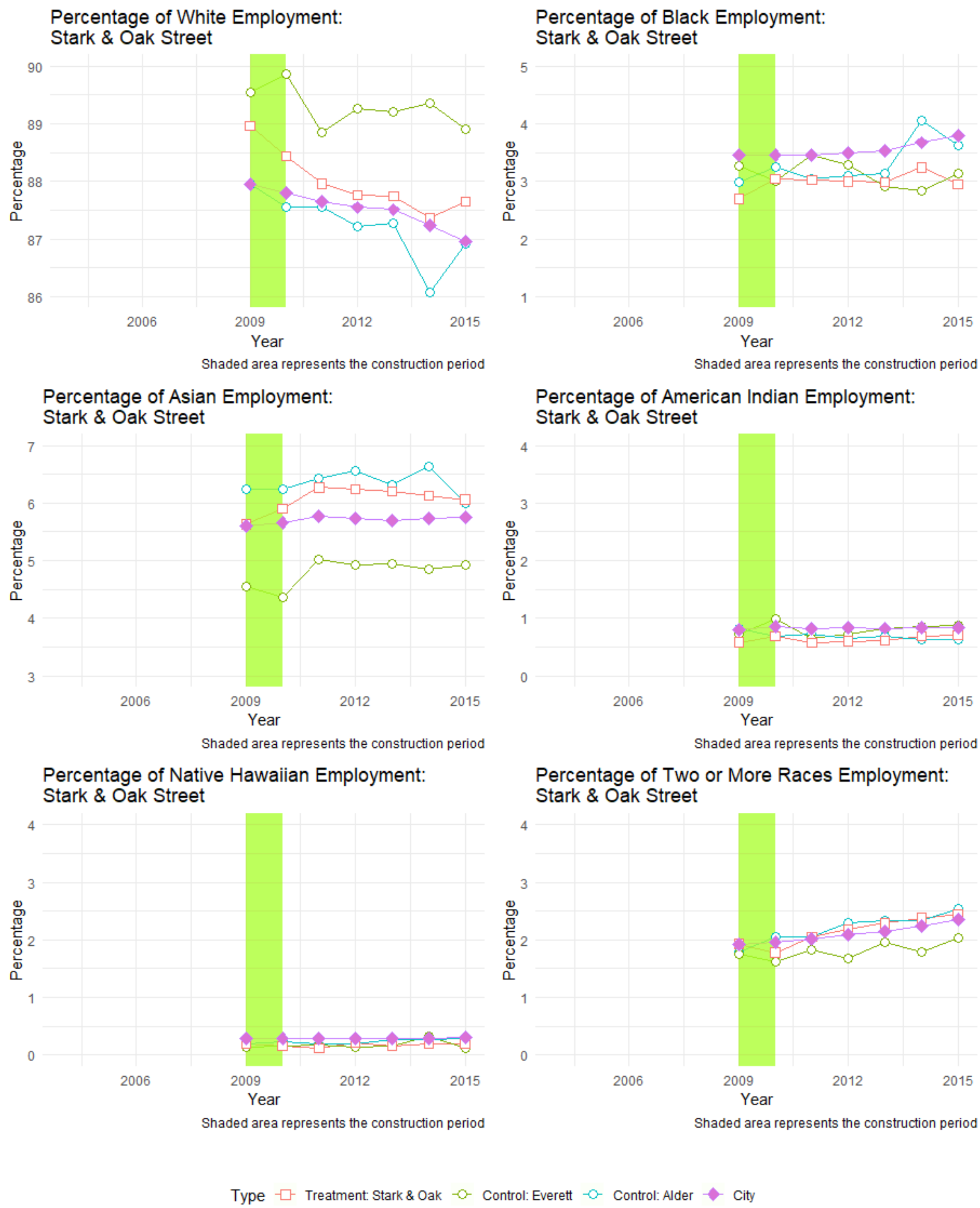


Figure 5-10. Stark & Oak Street Employment Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 5-15. Stark & Oak Street Employment Racial Composition Percentage Change (in percentage)

	Treatment	Control: Alder	Control: Everett	City
White	-0.25	-0.20	-0.12	-0.19
Black	1.58	3.51	-0.72	1.65
American Indian	3.48	-3.95	3.40	0.65
Asian	1.27	-0.65	1.32	0.48
Hawaiian	0.26	1.32	-0.61	1.05
Two or more races	4.40	1.27	2.70	3.76

Note: These percentage changes are calculated as the average annual percentage change between 2010 and 2015.

5.1.3.2.2 Residents

While there appears to be large fluctuations in the number and percentage of white and black residents on the Alder control corridor, this may be related to fuzzing of the LEHD data that we mentioned previously. The table below summarizes the average percentage change of the racial composition of residents along the treatment and control corridors. We observe large increases in the percentage of black residents on the treatment corridor and small decreases in other non-white residents. However, the changes are small (and quite possibly fluctuating purely due to data-fuzzing), and we do not observe any particular patterns in resident racial composition on the street improvement corridor that differs from the city as a whole.

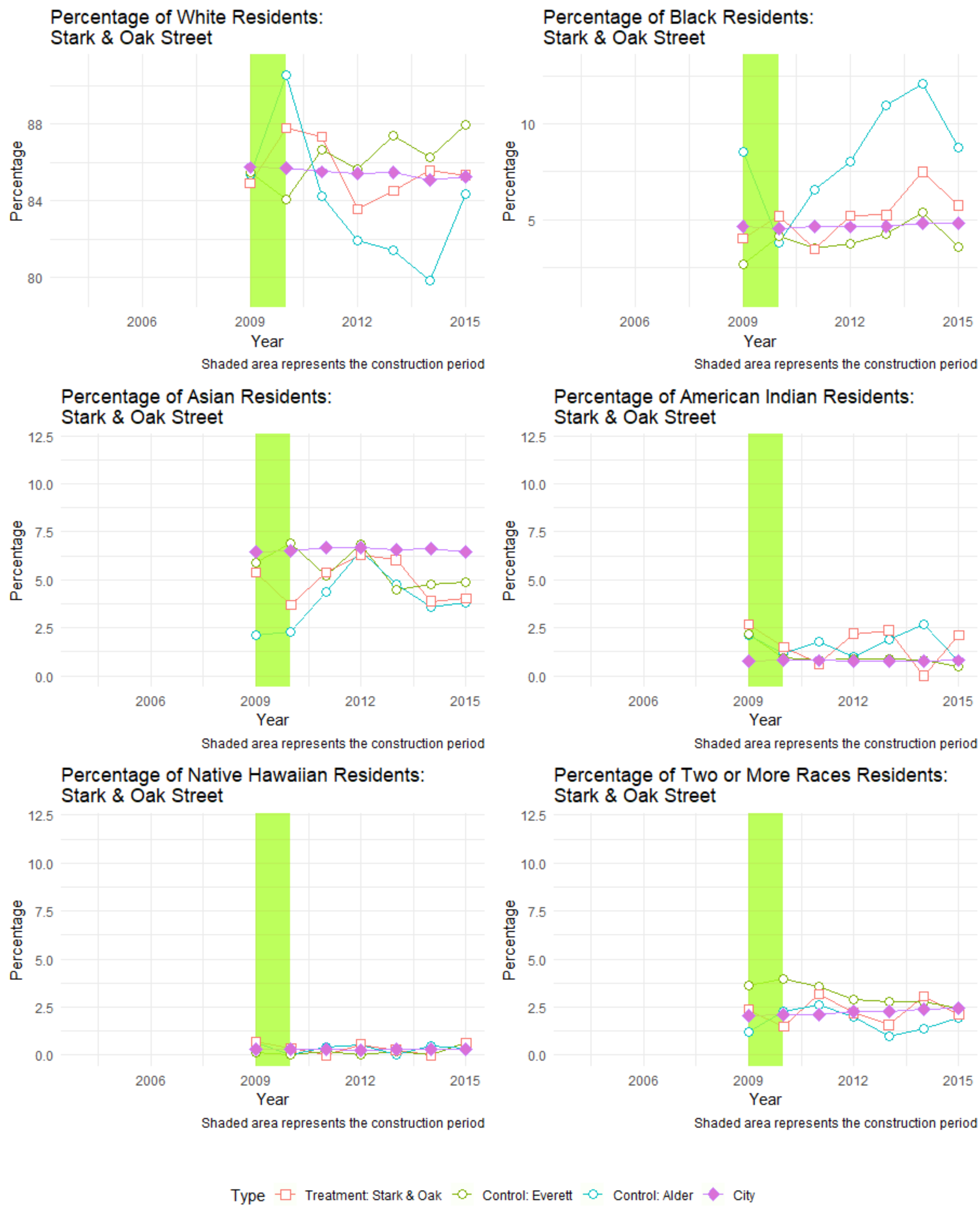


Figure 5-11. Stark & Oak Street Residents Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points; in addition, the range of y-axis is different from previous graph as well)

Table 5-16. Stark & Oak Street Residents Racial Composition Percentage Change (in percentage)

	Treatment	Control: Alder	Control: Everett	City
White	0.08	-0.20	0.48	-0.09
Black	7.11	0.47	5.55	0.51
American Indian	-3.46	-10.71	-12.88	0.25
Asian	-4.11	13.14	-2.90	-0.09
Hawaiian	-0.81	-6.23	64.44	0.37
Two or more races	-1.57	9.41	-5.45	2.91

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

5.1.3.3 Education

5.1.3.3.1 Employment

In terms of education attainment, the selected corridors had less college-level employment, but more bachelor's or above-level employment than the city as a whole. The treatment corridor generally has similar patterns as the corresponding control corridors. Percentage of bachelor's or above-level employment decreased while the other three categories all increased slightly.

5.1.3.3.2 Residents

In terms of residents' education level, we observe more fluctuation. In the treatment corridor, there were more residents with lower educational attainment and fewer residents with higher educational attainment when compared to the city as well as the control corridors. This might indicate a shift in the industrial sectors that exist along the treatment corridors and neighboring areas, with more jobs that require less education or non-conventional education.

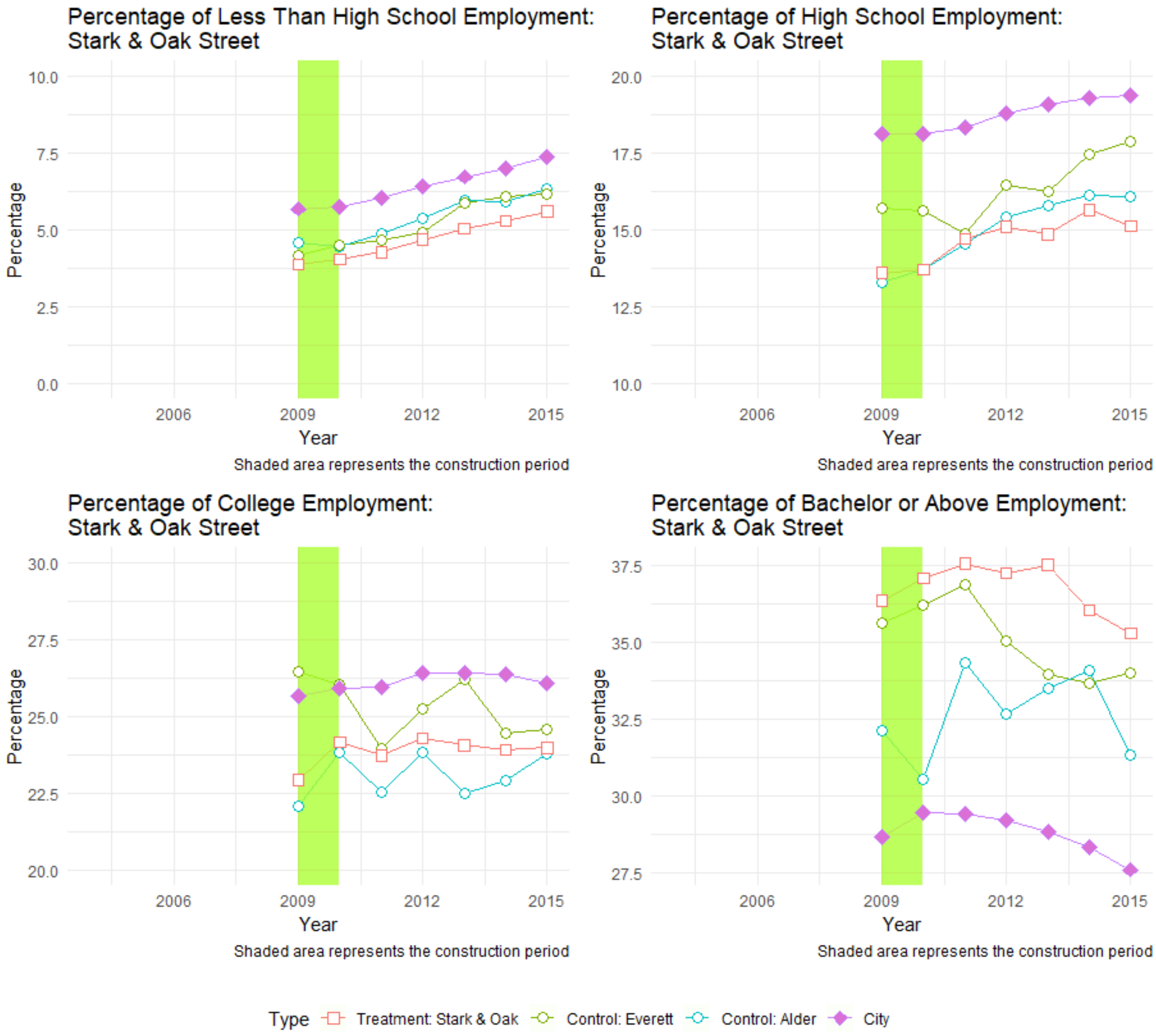


Figure 5-12. Stark & Oak Street Employment Education Attainment Level Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 5-17. Stark & Oak Street Employment Education Attainment Level Composition Percentage Change (in percentage)

	Treatment	Control: Alder	Control: Everett	City
Less than high school	7.50	6.27	8.07	4.92
High school	1.86	3.54	2.28	1.16
College	0.76	1.29	-1.17	0.28
Bachelor's or above	-0.49	-0.39	-0.75	-0.61

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

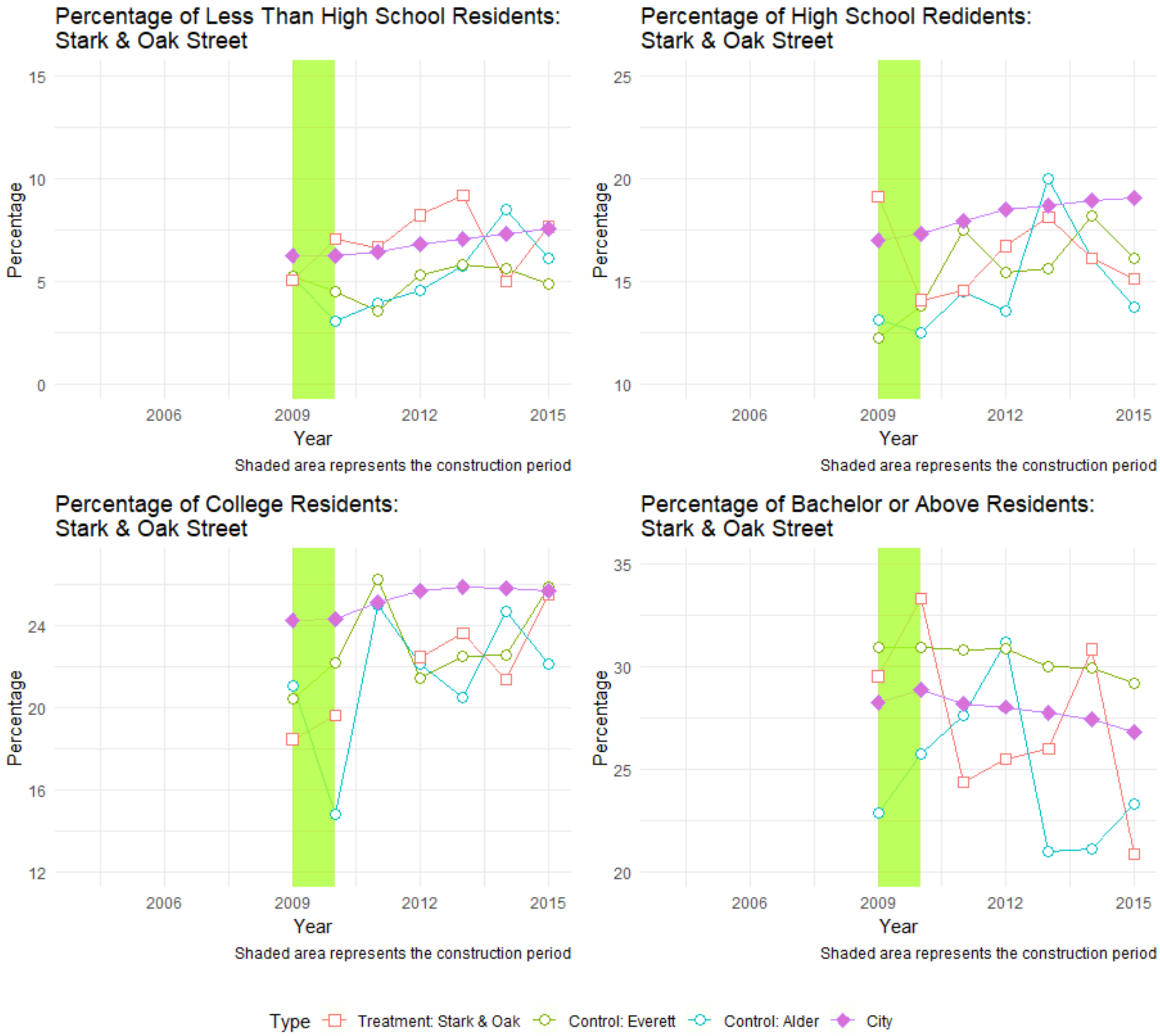


Figure 5-13. Stark & Oak Street Residents Education Attainment Level Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 5-18. Stark & Oak Street Employment Education Attainment Level Composition Percentage Change (in percentage)

	Treatment	Control: Alder	Control: Everett	City
Less than high school	8.70	2.97	-1.13	3.51
High school	-3.50	0.80	5.30	2.02
College	6.39	0.87	4.46	0.99
Bachelor's or above	-4.90	0.30	-0.95	-0.86

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

5.1.3.4 Gender

In terms of gender, the whole city experienced decreases in female employment. The trends were similar for all corridors and the city, except on the Everett control corridor where there was a slight increase in female employment after the recession period. Compared to employment gender composition, fewer female residents lived on the selected corridors.

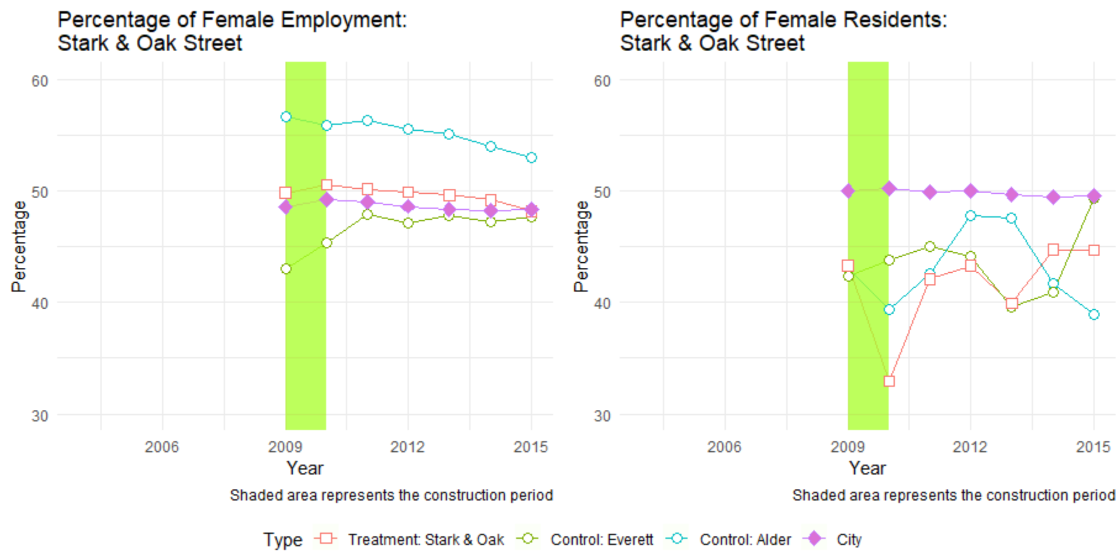


Figure 5-14. Stark & Oak Street Gender Composition Trend

In general, construction of bike lanes on the Stark and Oak corridor did not appear to result in any visible demographic changes compared to the corresponding control corridors or the city as a whole. The few noticeable patterns include more high-income employment on the treatment corridor after bike lane installation compared to the control corridors, and a higher percentage of employment with lower educational attainment across the city. We found that the treatment corridor followed similar trends of racial composition changes as the city and its control corridors. This preliminary distributional equity analysis of the demographic patterns along the Stark and Oak street improvement corridor should not be considered as a definitive indication that there are no equity or distributional concerns, and could benefit from additional research.

5.1.4 Stark & Oak Corridor Summary

We used three different data sources, LEHD employment data, QCEW data and NETS employment and sales revenue data, to analyze the economic and equity impacts of the street improvement on the Stark & Oak corridor. Each of these data sources was analyzed using the aggregated trend analysis, DID estimation and ITS estimation approaches, and we were able to conclude that:

- Three data sources generally showed similar impacts on economic outcome indicators of the bike lane installation on the Start and Oak corridor, indicating either no impact or positive impacts on employment and sales in the retail and food services sectors.

- In particular, aggregated trend analysis and ITS analysis of QCEW and NETS data all consistently show that the street improvement on the Stark and Oak corridor had positive and statistically significant impacts on retail employment and sales revenue.
- Analysis of the LEHD data generally showed no impact of the street improvement on retail and food employment. However, due to the fuzzy factor applied to the LEHD data mentioned previously in the data section, we believe that these results are less reliable than those using alternative data sources.
- Results from the limited demographic LEHD data do not indicate divergent patterns in the environmental justice indicators along the street improvement corridor when compared with the control corridors or the city.

6.0 CASE EXPLORATION: SAN FRANCISCO

6.1 POLK STREET CORRIDOR

San Francisco's Polk Street has been a popular street for many improvement projects over the decades. In 2000, the city completed a road diet project between Turk Street and Vallejo Street where a southbound lane was removed and, in 2009, street trees and lighting were upgraded between Sacramento and O'Farrell (a section of road diet). All blocks have either retail or food service employment along or at crossing streets on this corridor. As a comparison, we chose Van Ness Avenue (between California Street and Vallejo Street), containing 14 blocks.

Figure 6-1. Polk Street Corridor Map

6.1.1 Corridor Selection

In terms of business activity, both Polk Street and Van Ness Avenue are vital business corridors. As of 2008, the average business-related (retail and food and accommodation services) employment per block were 33 and 43 for treatment and comparison corridors, respectively. The treatment corridor had slightly less retail jobs than the control corridor, while their food and accommodation jobs were similar. We further compared their retail employment density percentile with San Francisco's all-block average. From the following table we could tell that the two corridors are located in similar percentile brackets for both retail and food and accommodation service employment, which indicates that the two corridors have similar levels of business activity.

Table 6-1. Comparison of Business Jobs Per Block Percentiles Among Polk Corridors in 2008

Corridor	Tot Emp.	Retail Emp.	Food Emp.	Tot (%)	Retail (%)	Food (%)
Polk St.	108	13	20	70-75	75-80	75-80
Van Ness Ave.	124	21	22	70-75	80-85	75-80

In addition, we compared business job share as a percentage of all other service jobs for each block. On the Polk Street treatment corridor 52% of all service jobs were business jobs, and the number for the Van Ness Avenue comparison corridor was 53%. There was also no significant difference between the jobs in the two corridors according to the t-test. We further compared the average business job annual growth rates before improvement completion, 2002-2008, on the two corridors. The annual growth rate for the treatment corridor was -0.5% compared to 0.6% for the comparison corridor, and the t-test indicates no statistically significant differences at a 95% confidence interval between the two corridors. In terms of street characteristics, all corridors are located in downtown San Francisco, although Van Ness is a busier arterial than Polk Street, with higher traffic volume. We found that Van Ness Avenue is an appropriate comparison corridor with our treatment corridor - Polk Street.

Table 6-2. Study and Comparison Corridor Selection Criteria (Polk Corridor)

<table>
<tr><th>Study site</th><th colspan="2" rowspan="2">Criteria</th><th>Comparison site</th></tr>
<tr><td>Polk Street</td><td>Van Ness Ave</td></tr>
<tr><td rowspan="2">• All 28 blocks have retail or food stores</td><td rowspan="2">Business Activity</td><td>Job density percentile</td><td>✓</td></tr>
<tr><td>Growth rate</td><td>✓</td></tr>
<tr><td></td><td>Street Characteristics</td><td>Geography proximity</td><td>✓</td></tr>
</table>

• Streetscape project with street trees and lighting upgrade		Travel volumes/ Speed limit	x
		Location in road network	x
• Completion in fall 2009 • LEHD available in 2004-2015	Time period/ Date	Time	✓
		Data	✓

6.1.2 Economic Outcome Analysis

6.1.2.1 LEHD Data

6.1.2.1.1 Aggregate Trend Analysis

The following table and graph show the aggregated trend analysis results for the Polk Street treatment corridor, its control corridor and at the city level. After the construction, the treatment corridor saw higher food employment compared to the control corridor and city level. Retail employment along the Polk Street corridor grew at a slower rate than Van Ness Avenue in the first-year post-improvement, but still outperformed retail employment growth in the city. However, it appears that these effects were not long lived. Retail employment experienced a large bump in the second year after construction, but employment in both the retail and food sectors dropped subsequently.

Table 6-3. Polk Corridor Aggregated Employment Changes Post-Improvement (LEHD Data)

Corridor	Baseline employment per block (2009)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Polk	8	17	2.2%	22.2%	20.4%	-5.4%	-7.22%	-0.72%
Van Ness	16	20	8.9%	16.9%	7.2%	-8.2%	1.64%	2.23%
San Francisco	19	24	-1.3%	3.3%	3.2%	2.5%	2.76%	2.14%

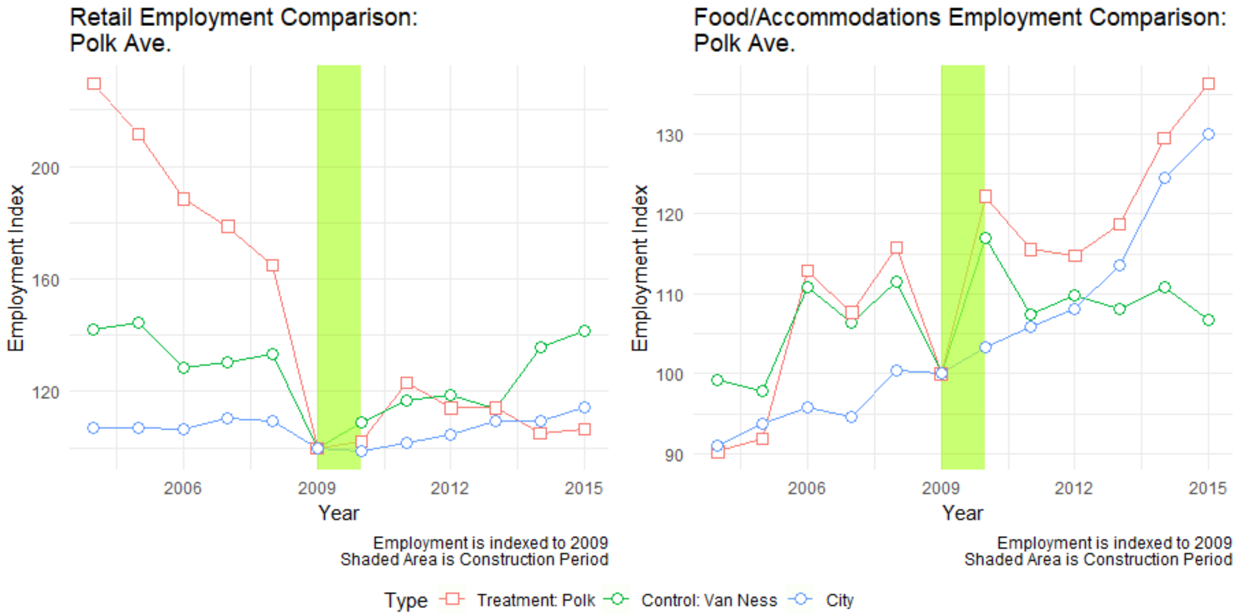


Figure 6-2. Aggregated Employment Trend of Polk Corridor and Control Corridors (LEHD Data)

6.1.2.1.2 Difference-in-Difference (DID)

We applied an econometric DID method to examine the impact on retail and food employment separately and the combination of the two (i.e., ‘business’ employment). A significant positive DID effect would indicate a positive impact (the installation of the new street improvement) of treatment on employment performance. The models do not show statistical significant influence of the street improvement on business employment.

Table 6-4. Polk Corridor DID Regression Results (LEHD Data)

	Dependent variable:		
	Retail Emp.	Food Emp.	‘Business’ Emp.
Control: Van Ness	348.714***	241.286***	590.000***
	46.582	25.600	42.779
Pre-post	-124.114**	82.600***	-41.514
	51.028	28.043	46.862
	115.586	-65.086	50.400
DID estimator: control	72.164	39.659	66.273
Constant	377.714***	510.000***	887.714***
	32.938	18.102	30.250
Observations	24	24	24
R2	0.867	0.866	0.946
Adjusted R2	0.847	0.846	0.938
Residual Std. Error (df = 30)	84.147	47.893	80.033
F Statistic (df = 5; 30)	43.452***	43.015***	116.841***

Note: *p<0.1; **p<0.05; ***p<0.01

6.1.2.1.3 Interrupted Time Series (ITS)

The ITS estimation coefficients represent a time series trend, the effect of treatment on employment level and changes in growth rate. On Polk Street, our ITS estimation shows that the street improvement led to a drop in the level of retail employment combined with a slope (growth rate) increase. The retail employment decreased continuously before 2008, but this trend reversed after 2009. Additional data points would possibly provide a better estimation on level and slope change. In addition, the street improvement had no apparent impact on food and accommodation employment.

Table 6-5. Polk Corridor Interrupted Time Series Analysis Results (LEHD Data)

	Dependent variable:		
	Retail Emp.	Food Emp.	'Business' Emp.
Time series	-50.464***	19.786**	-30.679**
	4.947	6.933	10.916
Level change	-231.971**	-109.257	-341.229
	86.961	121.204	190.823
Slope change	41.064***	7.314	48.379*
	9.697	13.515	21.279
Constant	579.571***	430.857***	1,010.429***
	22.247	31.007	48.817
Observations	12	12	12
R^2	0.955	0.780	0.564
Adjusted R^2	0.938	0.698	0.400
Residual Std. Error (df = 8)	26.323	36.688	57.761
F Statistic (df = 3; 8)	56.345***	9.462	3.448*

Note: *p<0.1; **p<0.05; ***p<0.01

6.1.2.2 Sales Tax Data

The retail sales tax data was provided by the San Francisco Controller's Office. Due to confidentiality, the data was cleaned and aggregated to the street-corridor level with block-face addresses. The data was divided into several categories of retail sales:

- Restaurant
- Standard: Apparel stores, department stores, drug stores, recreation products, florists, food markets, liquor stores, miscellaneous and other.
- Miscellaneous: Furniture/appliance stores, food processing equipment, auto parts/repair, new and used auto sales, service stations, building materials, office equipment, electronic equipment (business to business), business services, energy sales, chemical products, heavy and light industry, and equipment leasing.

To maintain consistency across different data sources, we categorized the sales tax data into the restaurant sector and retail sector, which is a combination of the standard and miscellaneous categories in the above description.

6.1.2.2.1 Aggregated Trend Analysis

The following table and graphs show the trend of sales changes across the Polk Street treatment corridor, Van Ness Avenue control corridor and at the city level. In general, retail sales decreased in both the treatment and control corridors, while restaurant sales increased across years with slight drops during the economic recession periods. Compared with the control corridor, the treatment corridor performed better economically after the street improvement took place, either decreasing less or increasing more than the control corridor.

Table 6-6. Polk Corridor Aggregated Sales Tax Changes Post-Improvement (Sales Tax Data)

Corridor	Baseline sales tax (2009)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Polk	130,507	156,573	-0.7%	15.3%	-4.0%	4.9%	2.11%	12.28%
Van Ness	919,640	244,775	-10.9%	-10.3%	0.4%	3.0%	8.32%	6.18%
San Francisco	97,734,706	32,188,164	4.1%	5.4%	10.9%	9.8%	7.57%	8.02%

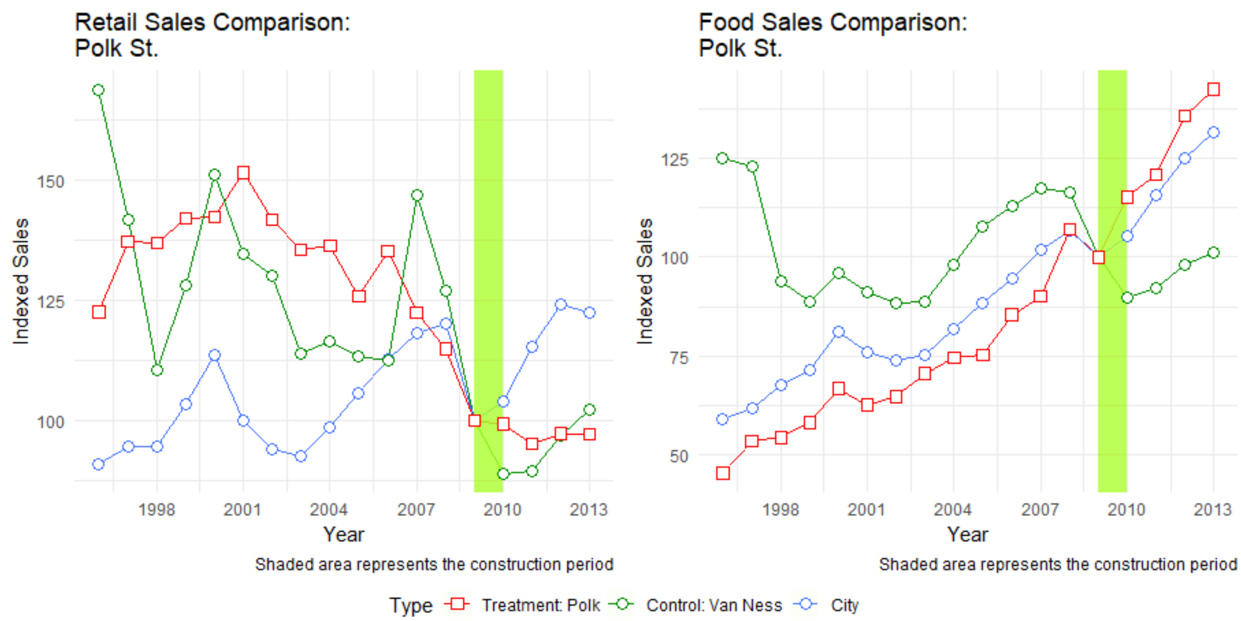


Figure 6-3. Aggregated Retail Sales Trend of Polk Corridor and Control Corridor (Sales Tax Data)

6.1.2.2.2 Difference-in-Difference Analysis

We further applied an econometric DID method to examine the impact on retail and food employment separately and the combination of the two (i.e., 'business' jobs). A significant positive DID effect would indicate a positive impact (the installation of the new street improvement) of treatment on employment performance. All three models consistently indicate positive significant impact of the street improvement on both retail and food sales tax receipts when compared with the Van Ness Avenue control corridor.

Table 6-7. Polk Corridor DID Regression Results (Sales Tax Data)
Polk Corridor DID Regression Results (LEHD Data)

	Dependent variable:		
	Retail Sales	Food Sales	'Business' Sales
Control: Van Ness	761,892*** 36,999	105,966.900*** 10,143.870	867,858.900*** 40,969.040
Pre-post	-37,473.050 64,084.740	85,305.790*** 17,569.700	47,832.740 70,960.450
DID estimator: control	- 175,725.40* 72.164	-96,514.890*** 24,847.300	-272,240.200** 100,353.200
Constant	377.714*** 90,629.510	-96,514.890*** 7,172.799	256,737.700*** 28,969.480
Observations	36	36	36

R2	0.938	0.787	0.939
Adjusted R2	0.932	0.767	0.933
Residual Std. Error (df = 30)	101,326.900	27,780.130	112,198.300
F Statistic (df = 5; 30)	160.627***	39.398***	164.700***

Note: *p<0.1; **p<0.05; ***p<0.01

6.1.2.2.3 Interrupted Time Series (ITS) Analysis

Additional interrupted time series models were estimated on sales tax receipts along the Polk Street corridor in San Francisco. The results indicate that the majority of increases in retail and restaurant sales tax receipts are mainly attributed to a time series trend, instead of resulting from the bike lane construction.

Table 6-8. Polk Corridor ITS Regression Results (Sales Tax Data)

	Dependent variable:		
	Retail Sales	Food Sales	'Business' Sales
Time series	-2,652.623***	6,552.514***	3,899.891***
	764.076	485.429	687.167
Level change	-47,590.470	-56,846.450	-104,436.900
	81,766.810	51,947.690	73,536.510
Slope change	3,776.781	9,242.180	13,018.960
	9,072.896	5,764.148	8,159.657
Constant	147,225.000***	109,512.800***	256,737.700***
	3,301.184	2,097.292	2,968.901
Observations	18	18	18
R^2	0.706	0.971	0.851
Adjusted R^2	0.642	0.965	0.819
Residual Std. Error (df = 8)	12,785.430	8,122.779	11,498.500
F Statistic (df = 3; 8)	11.181***	155.167***	26.600*

Note: *p<0.1; **p<0.05; ***p<0.01

6.1.2.3 NETS Data

6.1.2.3.1 Aggregated Trend Analysis

The following tables and figures present the employment and sales change before and after the street improvement on the Polk Street corridor using the NETS dataset. As described previously in the data section, economic data from two types of industry categories are presented here: Type I includes all retail and food service establishments on the abutting blocks of the corridor, and Type II includes a refined subset of establishments directly facing the corridor (block-face establishments). Since the treatment and control corridors in this particular scenario are neighboring streets parallel to each other, Type I block-level data on the two corridors may include overlapping establishments.In terms of the Type I industry (directly corresponding to LEHD industry categories), the treatment corridor experienced significant drops in both employment and sales after construction, especially in the retail sector. We observed some recovery in employment on the treatment corridor recovered afterwards, however, the economic performance between the treatment corridor and control corridor were mixed (Figure 6-4C and Figure 6-5C). However, employment growth in both the retail and food service sectors along Polk Street are generally keeping pace with the city as a whole.

Table 6-9. Polk Corridor Aggregated Employment Changes Post-Improvement (NETS Data, industry type I)

Corridor	Baseline employment (2009)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Polk	458	589	-23.80%	-2.72%	1.15%	8.03%	5.38%	0.81%
Van Ness	768	401	- [illegible]	-2.00%	-2.83%	6.61%	8.40%	11.45%
San Francisco	51,623	42,877	-4.85%	-3.08%	0.05%	4.88%	0.05%	5.49%

Table 6-10. Polk Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, Industry Type I)

Corridor	Baseline sales (2009)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Polk	67,367,782	23,052,300	-27.71%	-2.79%	0.68%	2.44%	5.75%	-1.43%
Van Ness	131,399,682	15,120,400	-21.86%	-2.56%	19.92%	-4.18%	10.10%	9.28%
San Francisco	6,415,883,226	1,652,120,450	-3.33%	-3.14%	-5.70%	-2.42%	1.21%	5.43%

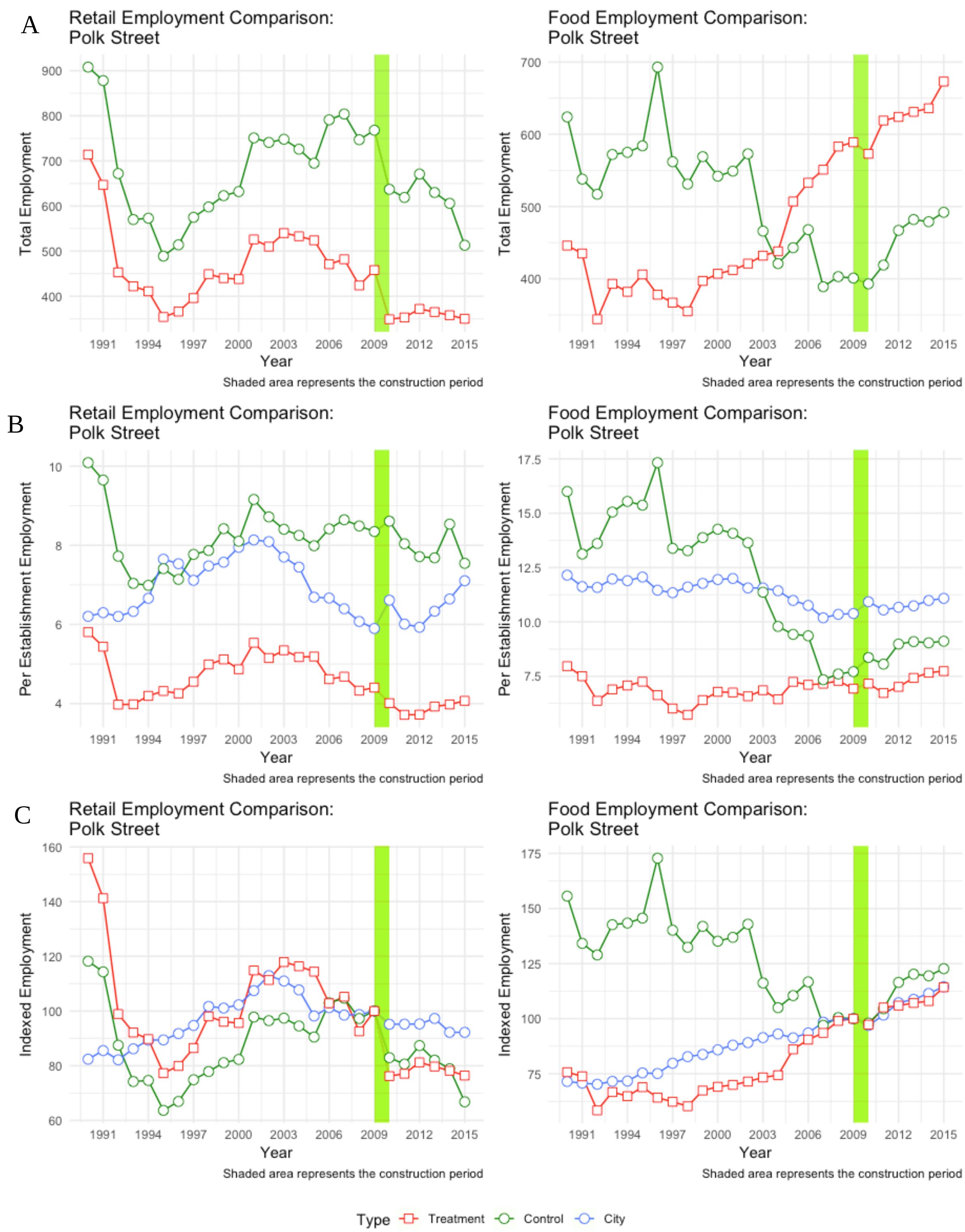


Figure 6-4. Aggregated Employment Trend of Polk Corridor and Control Corridor by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type I

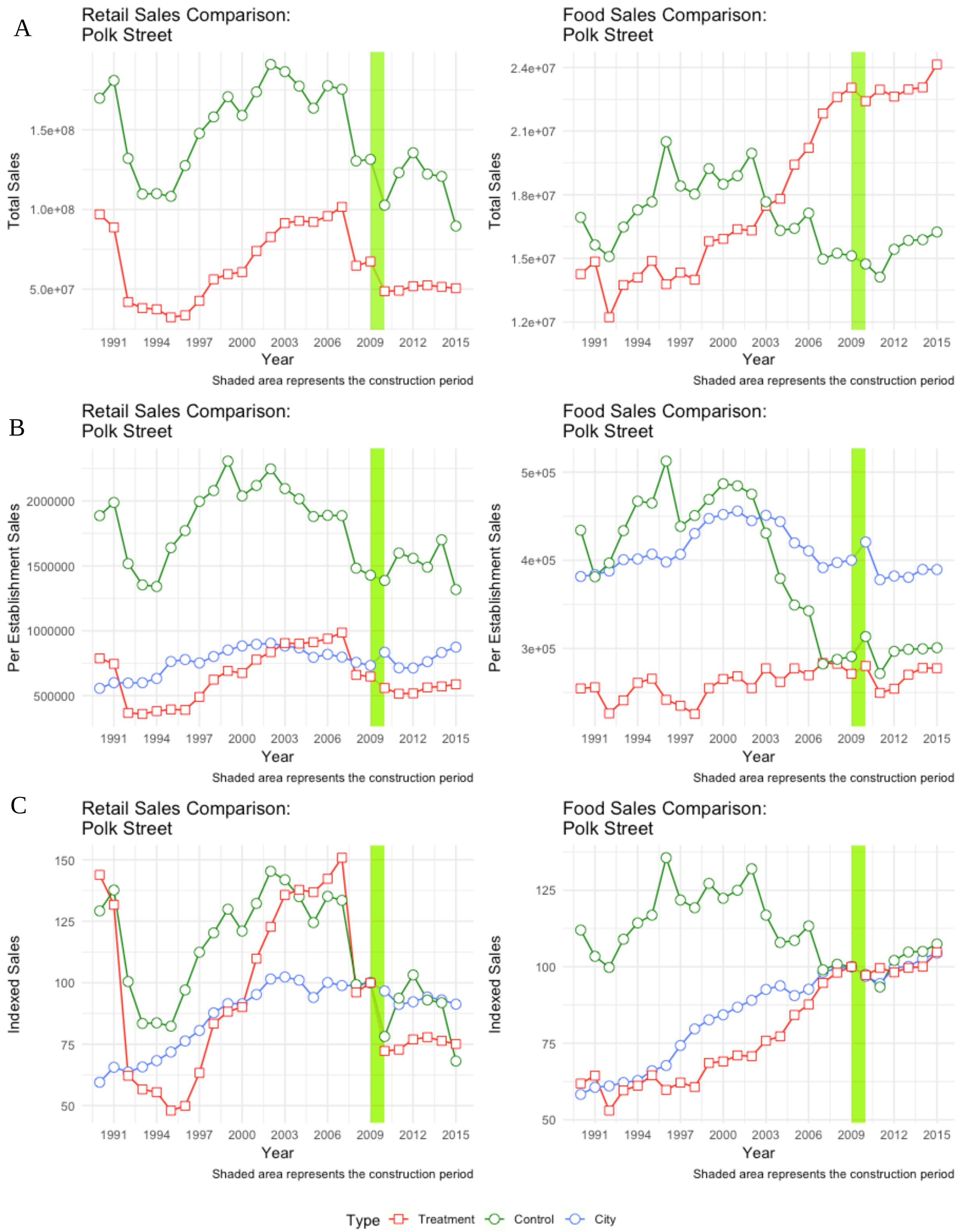


Figure 6-5. Aggregated Retail Sales Trend of Polk Corridor and Control Corridor by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type I

In terms of Type II block-face-level establishments, the treatment corridor experienced a smaller drop in employment compared to the control corridor (Figure 6-6A). Even after taking the number of establishments into account, the treatment corridor performed better than the control corridor, especially in the retail sector (Figure 6-6B). The indexed employment plots also indicate the treatment corridor outperformed the control corridor in retail employment; however, food services employment increased more on the control corridor in the years after the street improvement (Figure 6-6C). Figure 6-7 shows the trend of estimated sales in the retail sector, and it generally follows the same pattern as the employment trends.

Table 6-11. Polk Corridor Aggregated Employment Changes Post-Improvement (NETS Data, Industry Type II)

Corridor	Baseline employment (2009)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Polk	131	278	-12.97%	-3.96%	1.75%	4.49%	1.72%	1.08%
Van Ness	174	130	-52.87%	8.46%	-21.95%	2.12%	12.5%	9.03%
San Francisco	44,088	41,325	-4.88%	-2.74%	-0.96%	4.55%	1.24%	5.06%

Table 6-12. Polk Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, Industry Type II)

Corridor	Baseline sales (2009)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Polk	16,893,882	10,738,600	-8.05%	-2.79%	0.69%	0.77%	3.18%	0.52%
Van Ness	29,152,300	3,864,300	-77.31%	10.22%	-12.63%	2.06%	10.49%	10.67%
San Francisco	4,795,688,484	1,557,538,470	-3.25%	-2.91%	-6.09%	-0.75%	2.51%	5.03%

Figure 6-6. Aggregated Employment Trend of Polk Corridor and Control Corridor by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type II

Figure 6-7. Aggregated Retail Sales Trend of Polk Corridor and Control Corridor by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type II

6.1.2.3.2 Difference-in-Difference (DID) Analysis

DID analysis of the NETS dataset are presented below. Since the NETS dataset has longer historical data we chose to use the data between 2003 and 2015 for our analysis to maintain consistency, and limit this analysis to only the Type II establishments as these are the businesses that directly face the street improvement corridor. The results show a significant negative DID estimator for the control corridor, indicating that the treatment corridor had 75 more retail employment, 45 more food service employment, and $17,692,058 more in retail sales, on average, after the street improvement when compared to the control corridor.

Table 6-13. Polk Corridor DID Regression Results (NETS Data)

	Dependent variable:			
	Retail Emp.	Food Emp.	Retail Sales	Food Sales
Type Control	24.714*	-90.714***	7,113,005***	-5,228,171***
	13.103	16.700	2,545,951	527,516
Prepost	-24.514	28.171	-1,984,839***	867,462
	14.353	18.294	2,910,543	577,865
DID estimator	-75.914***	-45.086***	-17,692,058***	-1,334,549
	20.299	25.872	4,116,130	817,225
Constant	143.714***	264.429***	18,520,052***	10,362,557***
	9.265	11.809	1,878,748	373,010
Observations	24	24	24	24
R2	0.724	0.794	0.698	0.913
Adjusted R2	0.682	0.763	0.652	0.900
Residual Std. Error (df = 30)	24.513	31.244	4,970,699	986,893
F Statistic (df = 5; 30)	17.450***	25.642***	15.395***	69.673***

6.1.2.3.3 Interrupted Time Series (ITS) Analysis

We only conducted the ITS analysis on Type II block-face-level establishments using NETS data, and chose to utilize only the data between 2003 and 2015 for this analysis. The models indicate the street improvement on Polk Street had significant negative impact on retail employment and level of sales revenue, approximately a retail employment drop of 66 and retail sales decrease of $6,503,975 right after the street improvement; but the growth rate significantly increased after the street improvement. This is consistent with the aggregated trend analysis plots. The resulting negative level change post-improvement is intuitive as construction of infrastructure may have negatively affected the adjacent businesses, but the higher growth rates are indicative that the employment and sales levels are poised for recovery. The impact for food services was not significant, indicating the street improvement had no impact on food service employment and sales.

Table 6-14. Polk Corridor Employment ITS Regression Results (NETS Data)

	Dependent variable:			
	Retail Emp.	Food Emp.	Retail Sales	Food Sales
Time series	-7.607***	6.857***	7,26,450***	-326,232***
	1.359	3.264	150,835	94,505
Level change	-66.943***	-14.400	-6,503,975***	79,691
	23.752	57.058	2,636,818	1,652,092
Slope change	8.807***	0.143	887,783***	-116,962
	2.649	6.363	294,032	184,225
Constant	174.143***	236.000***	21,452,852***	9,057,629***
	6.076	14.597	674,556	422,641
Observations	12	12	12	12
R2	0.891	0.633	0.839	0.737
Adjusted R2	0.850	0.496	0.778	0.639
Residual Std. Error (df = 30)	7.198	17.271	798,146	500,076
F Statistic (df = 5; 30)	21.846***	4.605**	13.880***	7.481***

6.1.3 Distributional Analysis

The distributional analysis aims to track the demographic changes of residents along the treatment corridor, control corridor, and the city as a whole before and after the bike lane installation to examine any potential equity outcomes of the bike lane installation on the Polk Street corridor. This analysis is conducted using the LEHD dataset, where income indicators are available for a longer time period (covering both the pre- and post-construction periods), while gender, race and education indicators are only available starting in 2009.

6.1.3.1 Income

The treatment corridor Polk Street had relatively more business employment per block than the control corridor Van Ness Street. In terms of income-level distribution, both corridors had relatively constant low-income and medium-income jobs, and higher-income jobs increased since 2014 for both corridors. There was no apparent difference between the treatment and control corridors.

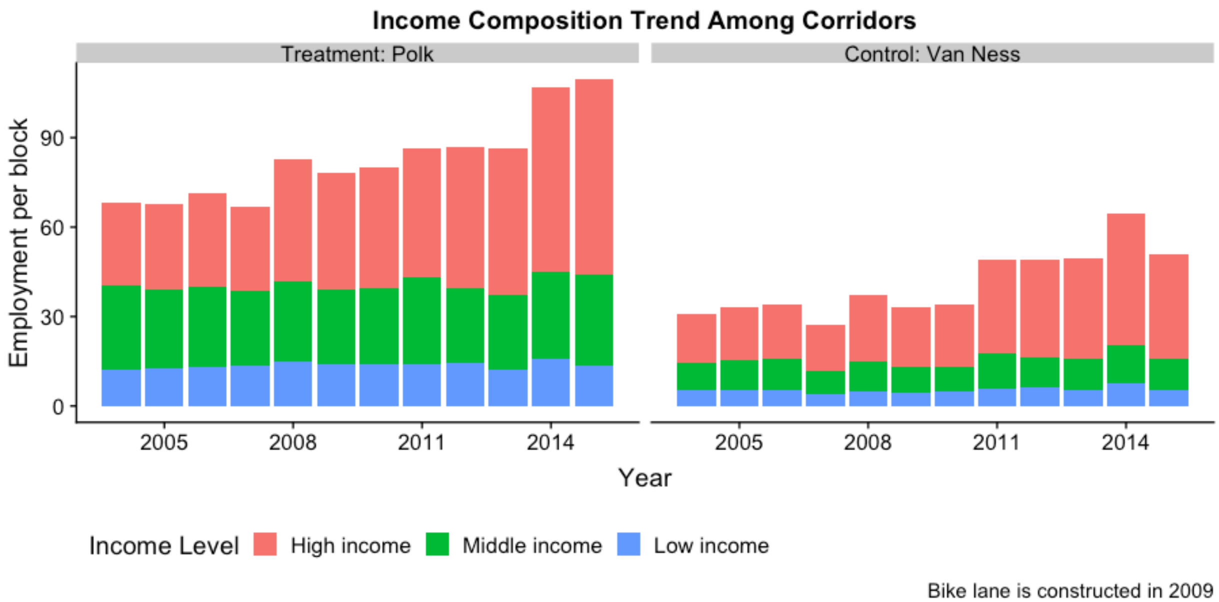


Figure 6-8. Polk Street Income-level Composition Trend

6.1.3.2 Race

6.1.3.2.1 Employment

In terms of employment racial composition, the treatment corridor Polk Street had a lower percentage of white and a higher percentage of Asian employment compared with the control corridor and city average. The whole city showed an increasing trend of white employment and decreasing trend of Asian employment. While there appeared to be a slightly greater increase of white employment and a decrease of Asian employment on the treatment corridor than the city average level, the trend was similar to the control corridor, indicating there were no apparent demographic changes on the corridor after the implementation of the street improvement.

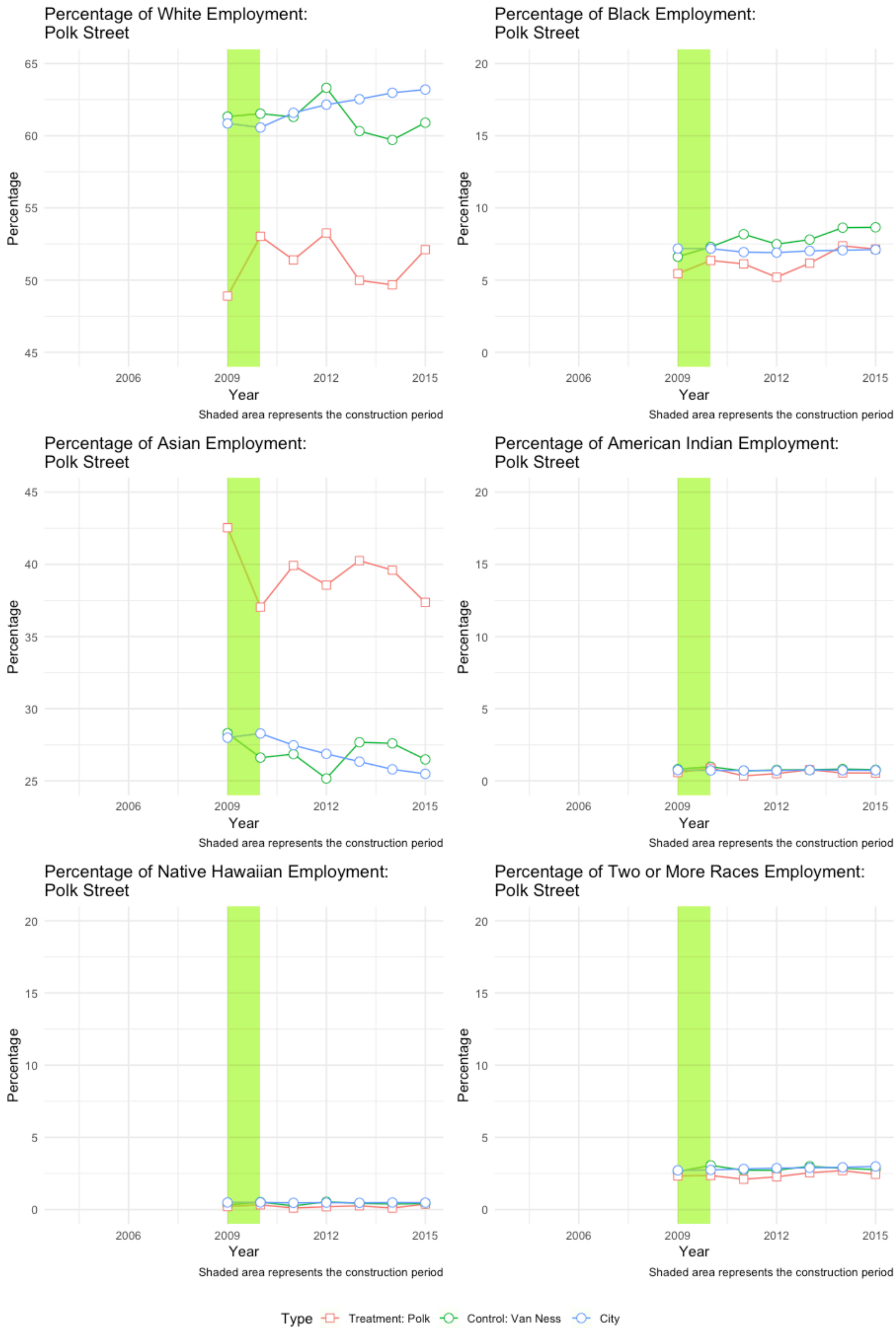


Figure 6-9. Polk Street Employment Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Due to the fuzzy factor applied in LEHD data, there are some unexpected fluctuations of the annual trend. Table 6-15 summarizes the average percentage change of the racial composition of residents along the treatment and control corridors between 2009 and 2015. While some percentage changes appear large (such as those for Black, American Indian, Hawaiian and Two or more races), the actual change may be still small due to the small number of these racial groups in the starting year. This table shows very similar results to the above graphs, that the employment racial composition trend on the Polk Street treatment corridor is similar to the Van Ness Avenue control corridor and the city.

Table 6-15. Polk Street Employment Racial Composition Percentage Change (in percentage)

	Treatment: Polk	**Control: Van Ness**	**City**
White	1.10	-0.11	0.64
Black	5.21	5.13	-0.17
American Indian	-0.92	-0.92	-0.47
Asian	-2.02	-1.07	-1.49
Hawaiian	13.64	5.07	-0.37
Two or more races	0.80	0.94	1.63

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

6.1.3.2.2 *Residents*

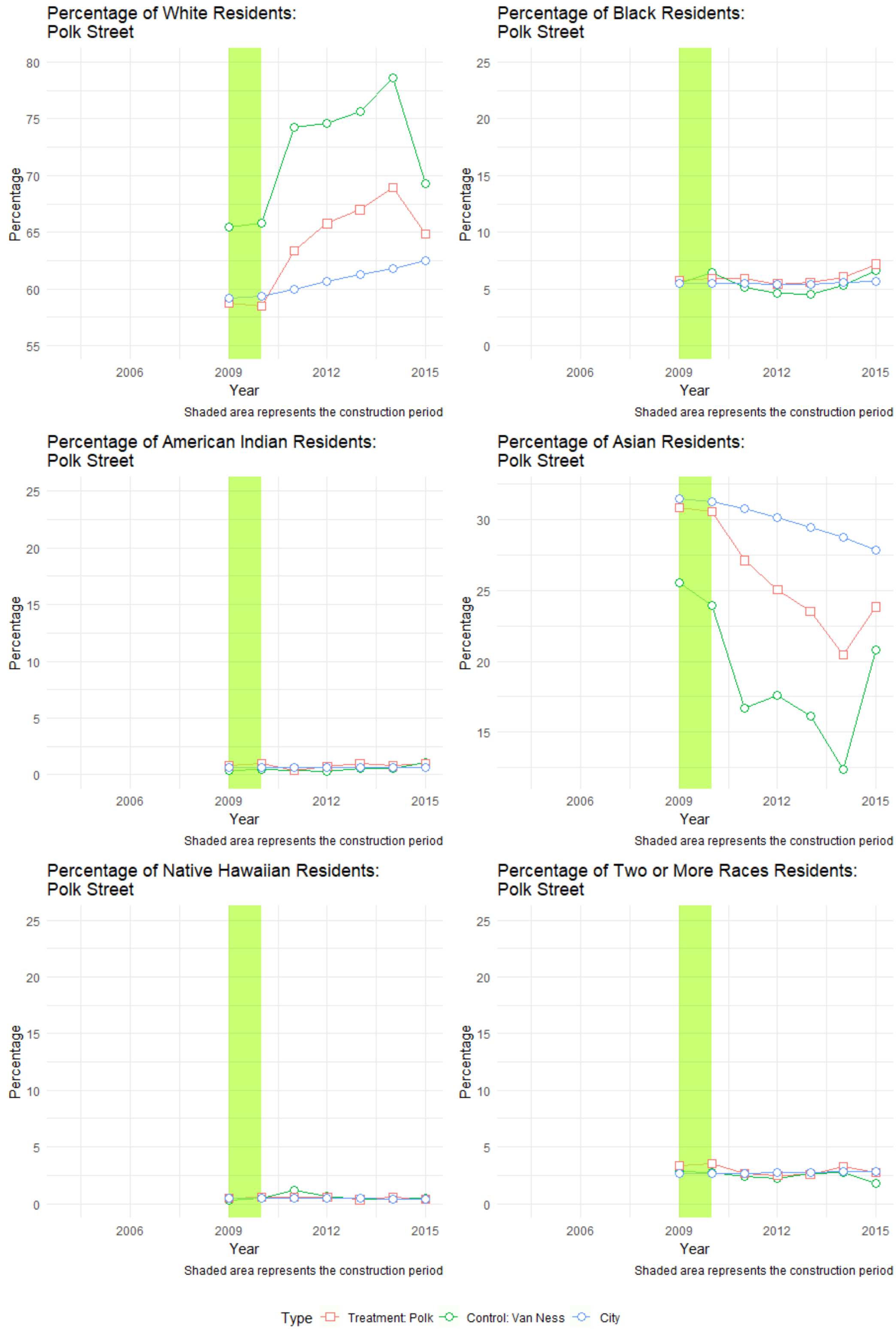


Figure 6-10. Polk Street Residents Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Similar to the employment racial composition, the percentage of white residents increased and the percentage of Asian residents decreased after 2009 across the board on the treatment corridor, control corridor and city level. The demographic changes of residents on the treatment corridor generally followed a similar pattern as the control corridor and the city. Again, Table 6-16 is consistent with Figure 6-10, showing no apparent divergence in the residential racial composition between the treatment corridor, control corridor and the city as a whole.

Table 6-16. Polk Street Residents Racial Composition Percentage Change (in percentage)

	Treatment: Polk	**Control: Van Ness**	**City**
White	1.73	0.96	0.64
Black	4.05	3.45	-0.17
American Indian	3.57	38.20	-0.46
Asian	-3.77	-3.12	-1.49
Hawaiian	-2.64	8.02	-0.37
Two or more races	-3.03	-6.33	1.63

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

6.1.3.3 Education

6.1.3.3.1 Employment

In terms of education attainment, the selected corridors had fewer bachelor's or above employment compared to the city average. The percentage of bachelor's or above employment decreased while the other three categories all increased slightly. Again, we found no significant difference between employment education levels on the treatment corridor when compared to the control corridor, as is evidenced in both Figure 6-11 and Table 6-17.

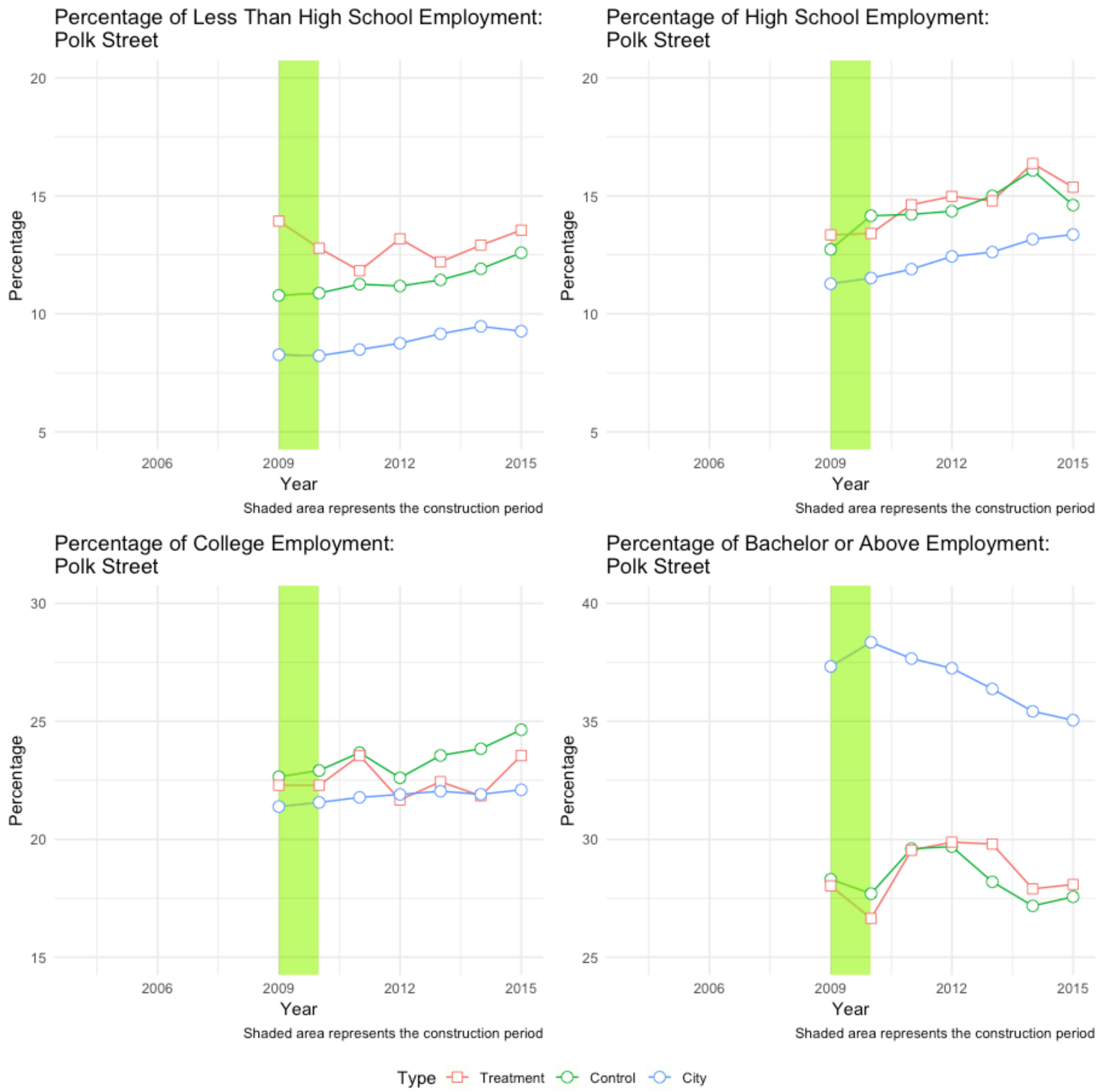


Figure 6-11. Polk Street Employment Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 6-17. Polk Street Employment Education Level Composition Percentage Change (in percentage)

	Treatment: Polk	**Control: Van Ness**	**City**
Less than high school	-0.46	2.79	2.02
High school	3.08	2.46	3.08

	Treatment: Polk	Control: Van Ness	City
College	0.94	1.46	0.55
Bachelor's or above	0.04	-0.44	-1.02

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

6.1.3.3.2 Residents

In terms of residents' education attainment, we again observe that the treatment corridor generally following a very similar pattern to the control corridor and the city. The average percentage change table (Table 6-18) demonstrates this as well.

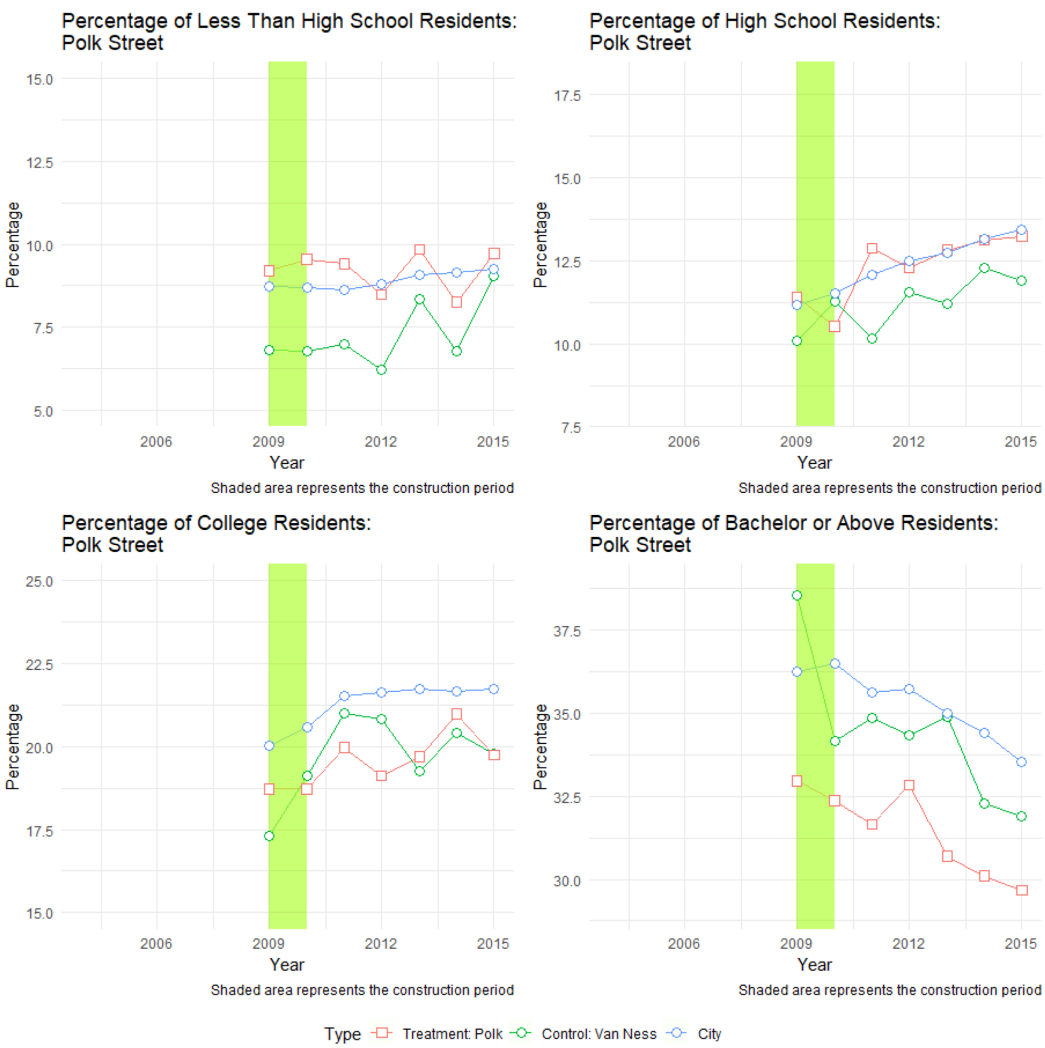


Figure 6-12. Polk Street Employment Education Level Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 6-18 Polk Street Residents Education Level Composition Percentage Change (in percentage)

	Treatment: Polk	Control: Van Ness	City
Less than high school	0.93	5.42	1.03
High school	2.68	3.01	3.35
College	0.92	2.37	1.44
Bachelor's or above	-1.67	-2.87	-1.26

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

6.1.3.4 Gender

In terms of gender, the whole city experienced a decrease in female employment. While there was greater fluctuation in female employment on the treatment corridor after 2009, it followed a similar decreasing trend as the control corridor and the city. Compared to employment gender composition, we observed fewer female residents on the treatment and control corridors.

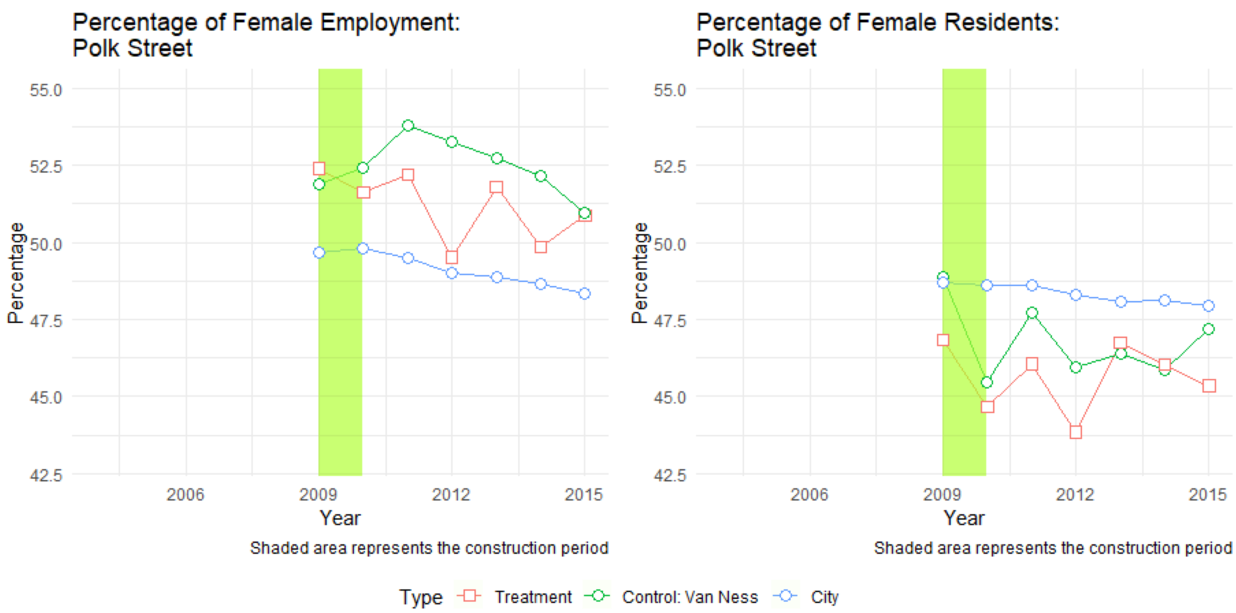


Figure 6-13. Polk Street Gender Composition Trend

In general, the street improvement on the Polk Street corridor did not appear to have caused any substantial demographic changes compared to the control corridor or the city as a whole. In particular, there was more high-income employment in the treatment and control corridors after 2014. In terms of racial composition, the data shows more Asian employment on the treatment corridor than on the control corridor and in the city. Although the treatment corridor followed a similar trend of racial composition change as the city and the control corridor, white employment increased while Asian employment decreased. The percentage of bachelor's or above employment decreased for both the corridors and the city. This preliminary distributional equity analysis of the demographic patterns along the Polk Street improvement corridor should not be considered as a definitive indication that there are no equity or distributional concerns, and could benefit from additional research.

6.1.4 Polk Street Corridor Summary

We used three different data sources, LEHD employment data, retail sales tax data and NETS employment and sales revenue data, to analyze the economic and equity impacts of the street improvement on the Polk Street corridor. Each of these data sources were analyzed using the aggregated trend analysis, DID estimation and ITS estimation approaches, and we were able to conclude that:

- NETS data and retail sales data analysis consistently indicate positive significant impacts of the Polk Street corridor street improvement on retail employment and sales, while analysis of the LEHD data did not yield significant results.

- The environment justice indicators generally followed similar trends in the treatment corridor, control corridor and the city. This indicates that the street improvement on the Polk Street corridor did not appear to have caused any substantial demographic changes compared to the control corridor or the city as a whole.

6.2 17TH STREET

17th Street has been a popular route for bicyclists in the recent decades, showing a 75% increase in bike traffic on the intersection at 17th Street and Valencia Avenue from 2006-2010. However, there was no bicycle-specific infrastructure. In 2011, a curbside bike lane was installed, replacing some parking spots between Church and Treat Avenue. The parallel corridor on 18th Street was selected to be the control corridor.

Figure 6-14. 17th Street Corridor Map

6.2.1 Corridor Selection

Both 17th Street and 19th Street are vital business corridors. As of 2010, the average business- related (retail and food and accommodation service) employment per block were 24 and 23 for the treatment and comparison corridors, respectively. The treatment corridor had slightly less retail jobs than the control corridor, but more food and accommodation jobs. We further compared their retail employment density percentile with the overall block average employment density in San Francisco. The following table shows that the per-block employment on both the treatment and control corridors are located in similar percentile brackets for both retail and food and accommodation services, which indicates that the two corridors have similar levels of business activity.

Table 6-19. Comparison of Business Jobs Per Block Percentiles Among 17th Street Corridors

Corridor	Tot Emp.	Retail Emp.	Food Emp.	Tot (%)	Retail (%)	Food (%)
17th Street	97	8	16	65-70	70-75	70-75
18th Street	70	14	9	60-65	75-80	60-65

In addition, we compared business jobs as a percentage of all other service jobs for each block. On the treatment corridor, 48% of all service jobs are business jobs and the number on the comparison corridor was 47%. The t-test confirms no significant difference as well. We further compared the average business job annual growth rates before the street improvement completion, 2002-2010, for the two corridors. The annual growth rate on the treatment corridor was 2.2% compared to 8.1 % for the comparison corridor. The t-test indicates no statistically significant differences at the 95% confidence interval between the two corridors. In terms of street characteristics, 17th and 18th streets are both local streets, parallel to each other, located in the Mission District of San Francisco. We find that 18th Street is an appropriate comparison corridor for our treatment corridor – 17th Street.

Table 6-20. Study and Comparison Corridor Selection Criteria (17th Street Corridor)

<table>
<tr><th>Study site</th><th colspan="2" rowspan="2">Criteria</th><th>Comparison site</th></tr>
<tr><td>17th Street</td><td>18th Street</td></tr>
<tr><td rowspan="2">• All 28 blocks have retail or food stores</td><td rowspan="2">Business Activity</td><td>Job density percentile</td><td>✓</td></tr>
<tr><td>Growth rate</td><td>x</td></tr>
<tr><td rowspan="3">• Streetscape project with street trees and lighting upgrade</td><td rowspan="3">Street Characteristics</td><td>Geography</td><td>✓</td></tr>
<tr><td>Travel volumes/</td><td>✓</td></tr>
<tr><td>Location in road</td><td>✓</td></tr>
<tr><td rowspan="2">• Completion in fall 2011
• LEHD available in 2004-2015</td><td rowspan="2">Time period/ Date</td><td>Time</td><td>✓</td></tr>
<tr><td>Data</td><td>✓</td></tr>
</table>

6.2.2 Economic Outcome Analysis

6.2.2.1 LEHD Data

6.2.2.1.1 Aggregated Trend Analysis

The following table and graph show the aggregated trend analysis of LEHD data on the 17th Street treatment corridor, its control corridor and at the city level. In the year after construction, retail employment on the treatment corridor increased significantly (28.79%), growing much more than its corresponding control corridor and the city. However, this performance was not persistent, and employment levels lagged behind that of the control corridor in subsequent years. Employment growth on the treatment corridor has been similar to the employment trends in the city, while the control corridor experienced greater growth after 2011.

Table 6-21. 17th Street Corridor Aggregated Employment Changes Post-Improvement (LEHD Data)

Corridor	Baseline employment per block (2011)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
17th Street	8	16	28.79%	8.90%	-7.30%	9.26%	6.48%	-6.73%
18th Street	14	9	6.44%	32.13%	6.57%	43.7%	11.35%	15.39%
San Francisco	17	24	2.76%	2.13%	4.56%	5.12%	0.13%	9.51%

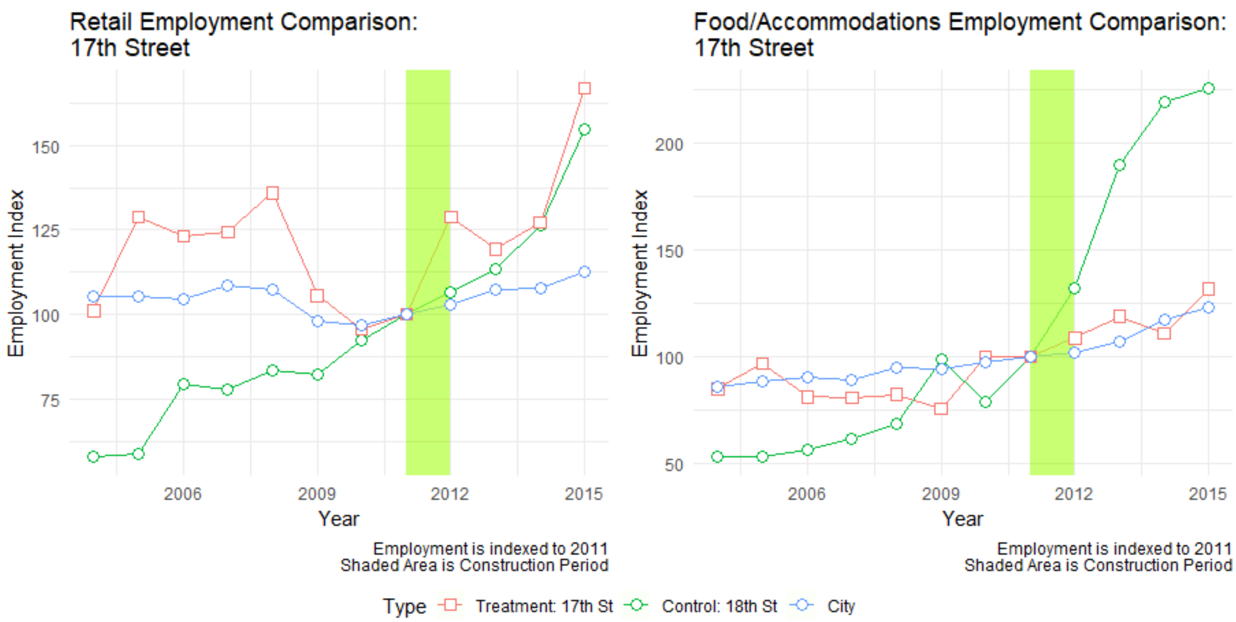


Figure 6-15. Aggregated Employment Trend of 17th Street Corridor and Control Corridors (LEHD Data)

6.2.2.1.2 Difference-in-Difference (DID) Analysis

The DID analysis aims to examine the impact on retail and food employment separately and the combination of the two (i.e., 'business' jobs). All three DID models on LEHD data indicate a negative impact of street improvement on retail and food employment since the DID estimators were statistically significant, showing that the control corridor has more employment. However, these results are primarily driven by the fact that the control corridor experienced quite significant economic growth after 2011, possibly due to external reasons unrelated to the lack of street improvements.

Table 6-22. 17th Corridor DID Regression Result (LEHD Data)

	Dependent variable:		
	Retail Emp.	Accommodations Emp.	'Business' Emp.
TypeControl	83.000***	-87.667***	-4.667
	(23.524)	(26.959)	(46.321)
prepost	39.556	102.333**	141.889**
	(33.267)	(38.126)	(65.508)
TypeControl:prepost	137.333***	267.333***	404.667***
	(47.047)	(53.919)	(92.642)
Constant	209.778***	304.000***	513.778***
	(16.634)	(19.063)	(32.754)
Observations	24	24	24
R^2	0.759	0.836	0.800
Adjusted R^2	0.722	0.811	0.770
Residual Std. Error (df = 20)	49.901	57.189	98.262
F Statistic (df = 3; 20)	20.953***	34.003***	26.697***
Note:	*p<0.1;* ***p<0.05;*** p<0.01		

*p<0.1; **p<0.05; ***p<0.01

6.2.2.1.3 Interrupted Time Series (ITS) Analysis

The ITS estimation coefficients represent a time series trend, the effect of treatment on employment level and changes in growth rate, without relying on a control corridor for comparison. ITS analysis of LEHD data shows a very different result than the DID analysis of the same data. While retail employment dropped by 440 jobs directly after the street improvement installation, the annual growth rate was 44 greater than before. The resulting negative change post-improvement is intuitive as construction of infrastructure may have negatively affected the adjacent businesses, but the higher growth rates are indicative that the retail employment levels are poised for recovery. In addition, the ITS analysis showed that there was no apparent impact on food/accommodation employment.

Table 6-23. 17th Corridor ITS Regression Results (LEHD Data)

	Dependent variable:		
	Retail Emp.	Accommodations Emp.	'Business' Emp.
ts_year	-1.500	7.667	6.167
	(3.672)	(4.567)	(6.202)
prepost	-440.944*	-95.833	-536.778
	(222.824)	(277.109)	(376.327)
ts_year:prepost	44.500*	13.833	58.333
	(20.447)	(25.428)	(34.532)
Constant	217.278***	265.667***	482.944***
	(20.665)	(25.700)	(34.902)
Observations	12	12	12
R^2	0.532	0.737	0.752
Adjusted R^2	0.356	0.638	0.659
Residual Std. Error (df = 8)	28.446	35.376	48.042
F Statistic (df = 3; 8)	3.029*	7.462**	8.073***
Note:	*p<0.1;* ***p<0.05;*** p<0.01		

6.2.2.2 NETS Data

6.2.2.2.1 Aggregated Trend Analysis

The following tables and figures present the employment and sales change before and after the street improvement on 17th Street using the NETS dataset. As described previously in the data section, economic data from two types of industry categories are presented here: Type I includes all retail and food service establishments on the abutting blocks of the corridor, and Type II includes a refined subset of establishments directly facing the corridor (block-face establishments). Since the treatment and control corridors in this particular scenario are neighboring streets parallel to each other, Type I block-level data on the two corridors may include overlapping establishments.

In terms of the Type I industry (directly corresponding to LEHD industry categories), the treatment corridor retail employment and sales remained nearly constant, while food service employment and sales increased significantly. After the construction year, employment and sales growth rates slowed down on the treatment corridor, while the control corridor continued to grow significantly in food service employment and sales.

Table 6-24. 17th Street Corridor Aggregated Employment Changes Post-Improvement (NETS Data, Industry Type I)

Corridor	Baseline employment (2011)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
17th Street	343	466	0.87%	21.46%	-0.87%	5.48%	-13.99%	2.68%
18th Street	307	266	4.51%	24.10%	1.43%	18.37%	-2.83%	5.99%
San Francisco	49,148	43,582	0.05%	5.49%	2.12%	1.45%	-5.20%	2.45%

Table 6-25. 17th Street Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, Industry Type I)

Corridor	Baseline sales (2011)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
17th Street	67,367,782	23,052,300	-0.77%	19.61%	-2.40%	5.44%	-13.71%	3.15%
18th Street	131,399,682	15,120,400	-1.78%	20.76%	-1.42%	19.94%	-0.29%	7.19%
San Francisco	5,848,031,129	1,561,551,388	1.21%	5.43%	2.13%	-0.49%	-1.26%	2.50%

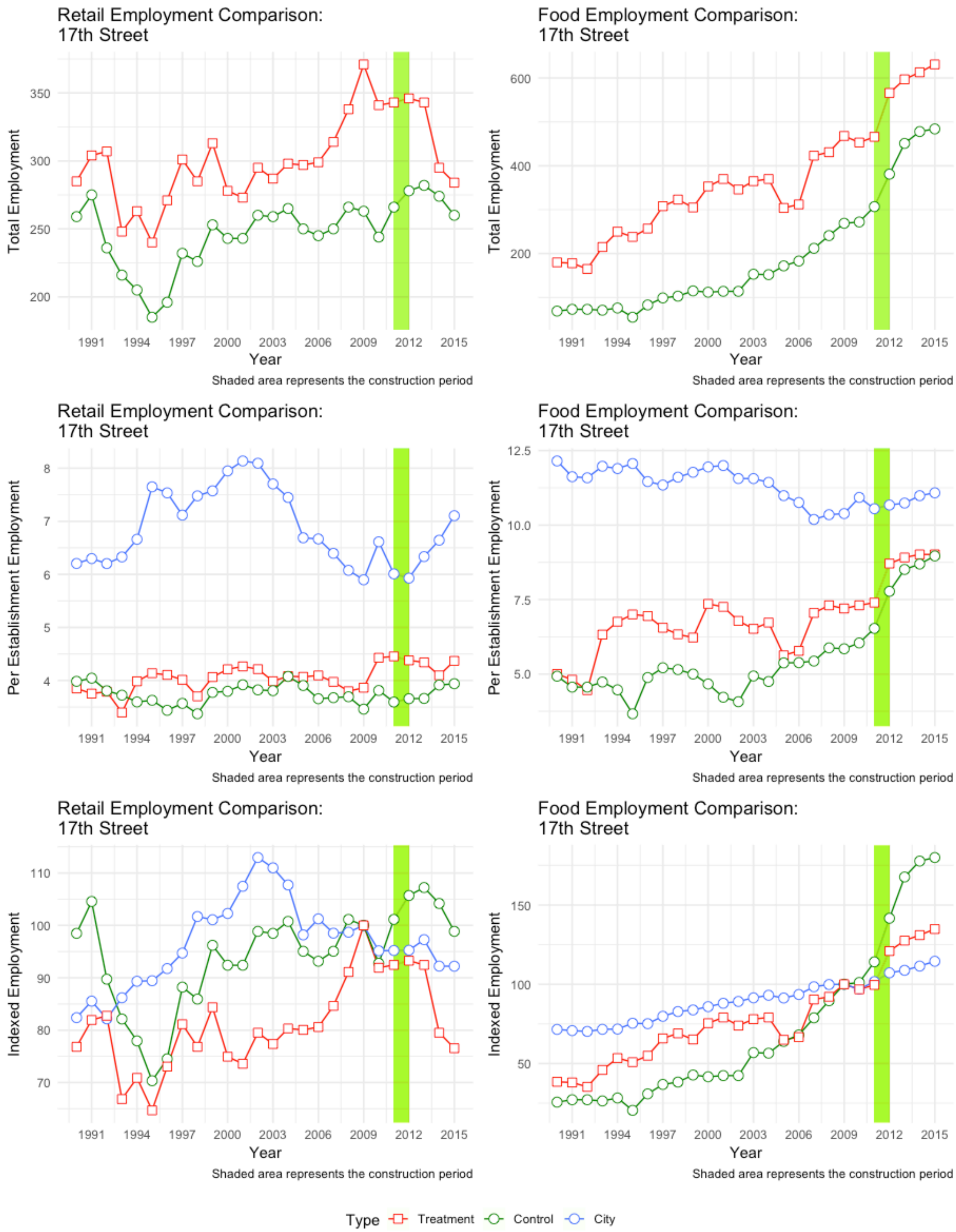


Figure 6-16. Aggregated Employment Trend of 17th Street Corridor and Control Corridor by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type I

Figure 6-17. Aggregated Sales Trend of 17th Street Corridor and Control Corridor by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type I

Within the more refined Type II-industry categories, retail employment and sales on the 17th Street treatment corridor increased significantly, while food service remained stagnant. This result differs from the trends of Type I-industry categories, highlighting the importance of separating Type I and Type II-industry categories as well as pinpointing establishments that directly face the street improvement corridor. The retail economy on the treatment corridor maintains consistent growth after the construction year of street improvement, while food service remains flat across all years.

Table 6-26. 17th Street Corridor Aggregated Employment Changes Post-Improvement (NETS Data, Industry Type II)

Corridor	Baseline employment (2011)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
17th Street	21	38	14.28%	0%	8.33%	0%	15.38%	0%
18th Street	12	130	-8.33%	7.69%	-27.27%	0%	-12.50%	0%
San Francisco	41,532	42,022	1.24%	5.06%	2.79%	1.41%	-5.22%	2.31%

Table 6-27. 17th Street Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, Industry Type II)

Corridor	Baseline sales (2011)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
17th Street	1,489,900	1,421,200	13.64%	-1.40%	8.21%	-0.66%	46.02%	0.78%
18th Street	131,399,682	15,120,400	-10.79%	9.45%	-26.21%	0.29%	-8.20%	0.01%
San Francisco	5,848,031,129	1,561,551,388	2.51%	5.03%	3.06%	-0.40%	-1.88%	2.39%

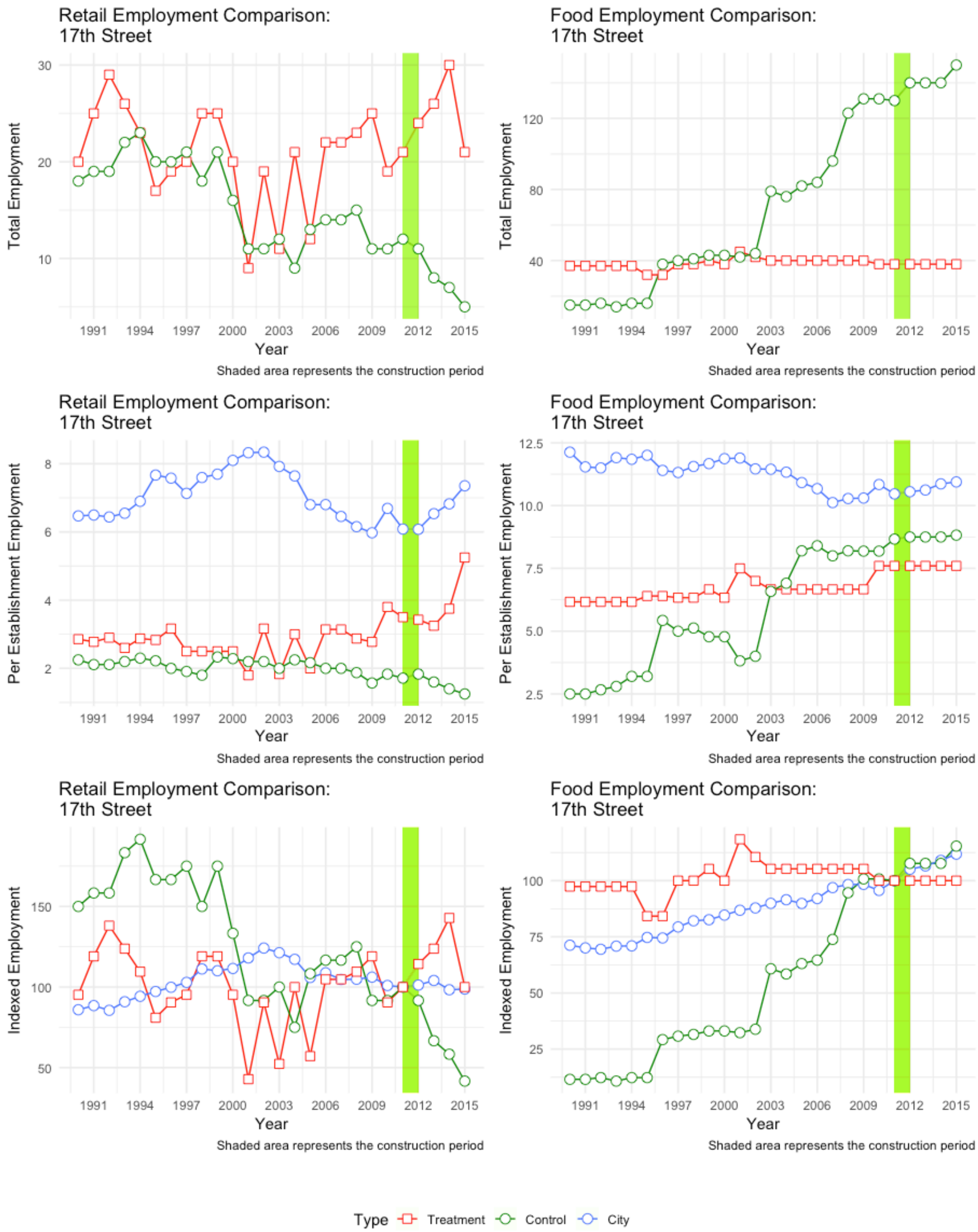


Figure 6-18. Aggregated Employment Trend of 17th Street Corridor and Control Corridor by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type II

Figure 6-19. Aggregated Sales Trend of 17th Street Corridor and Control Corridor by NETS Data (A: Establishment; B: Employment; C: Retail Sales) – Industry Type II

6.2.2.2.2 Difference-in-Difference (DID) Analysis

DID analysis of the NETS dataset are presented below. Since the NETS dataset has longer historical data, we chose to use the data between 2005 and 2015 for our analysis to maintain consistency, and limit this analysis to only the Type II establishments as these are the businesses that directly face the street improvement corridor. The results indicate the street improvement had significant positive impact on retail employment and sales on 17th Street, but negative impacts on food service employment and sales. The 17th Street treatment corridor had nine more retail jobs and $917,585 more in retail sales than the 18th Street control corridor, but 25 fewer food jobs and $688,223 less in food sales after the street improvement.

Table 6-28. 17th Street Corridor DID Regression Results (NETS Data)

	Dependent variable:					
	Employment			Sales		
	Retail	Food	Business	Retail	Food	Business
Type: Control	-9.714***	80.143***	70.429***	-902,914.300***	2,736,743.000***	1,833,829.000***
	(1.243)	(6.935)	(6.624)	(119,641.400)	(213,095.800)	(233,716.900)
Pre/post	3.381*	-1.143	2.238	552,233.300***	-37,052.380	515,181.000
	(1.604)	(8.953)	(8.552)	(154,456.400)	(275,105.400)	(301,727.300)
DID estimator: control	-9.286***	25.190*	15.905	-917,585.700***	688,223.800*	-229,361.900
	(2.269)	(12.661)	(12.094)	(218,434.300)	(389,057.800)	(426,706.800)
Constant	22.286***	39.143***	61.429***	1,658,100.000***	1,442,686.000***	3,100,786.000***
	(0.879)	(4.903)	(4.684)	(84,599.240)	(150,681.500)	(165,262.800)
Observations	20	20	20	20	20	20
R^2	0.910	0.936	0.922	0.907	0.946	0.842
Adjusted R^2	0.894	0.925	0.907	0.890	0.935	0.812
Residual Std. Error (df = 16)	2.325	12.973	12.393	223,828.500	398,665.600	437,244.400
F Statistic (df = 3; 16)	54.179***	78.573***	62.893***	52.305***	92.713***	28.429***
Note:	*p<0.1;* ***p<0.05;*** p<0.01					

6.2.2.2.3 Interrupted Time Series (ITS) Analysis

We only conducted the ITS analysis on Type II, block-face-level establishments using NETS data, and chose to utilize only the data between 2005 and 2015 for this analysis. However, ITS analysis indicates that there was no particular impact of the bike lane's installation on retail and food for both employment and sales.

Table 6-29. 17th Street Corridor ITS Regression Results (NETS Data)

	Dependent variable:					
	Employment			Sales		
	Retail	Food	Business	Retail	Food	Business
Yearly trend	-0.000	-0.429***	-0.429	-23,382.140	-7,600.000	-7,600.000
	(0.554)	(0.101)	(0.621)	(62,146.500)	(4,531.211)	(4,531.211)
Level change	30.881	-3.714	27.167	-1,189,110.000	-249,852.400	-249,852.400
	(23.139)	(4.218)	(25.919)	(2,594,818.000)	(189,192.800)	(189,192.800)
Slope change	-2.500	0.429	-2.071	168,932.100	22,800.000	22,800.000
	(2.146)	(0.391)	(2.404)	(240,692.400)	(17,549.310)	(17,549.310)
Constant	22.286***	41.714***	64.000***	1,798,393.000***	1,488,286.000***	1,488,286.000***
	(3.505)	(0.639)	(3.926)	(393,049.000)	(28,657.900)	(28,657.900)
Observations	10	10	10	10	10	10
R^2	0.414	0.821	0.303	0.518	0.590	0.590
Adjusted R^2	0.122	0.732	-0.045	0.277	0.385	0.385
Residual Std. Error (df = 6)	2.932	0.535	3.285	328,848.400	23,976.920	23,976.920
F Statistic (df = 3; 6)	1.415	9.200**	0.870	2.152	2.877	2.877
Note:	*p<0.1;* ***p<0.05;*** p<0.01					

6.2.3 Distributional Analysis

The distributional analysis aims to track the demographic changes of residents along the treatment corridor, control corridor, and the city as a whole before and after the bike lane installation to examine any potential equity outcomes of the bike lane installation on the 17th Street corridor. This analysis is conducted using the LEHD dataset, where income indicators are available for a longer time period (covering both the pre- and post-construction periods), while gender, race and education indicators are only available starting in 2009.

6.2.3.1 Income

The income-level composition remained relatively constant before 2013, while the high-income employment increased sharply after 2014 on the treatment corridor. On the control corridor, income-level composition stayed relatively constant across the years. In general, there was not much difference in the employment income level between the treatment and control corridors after the bike lane installation on 17th street.

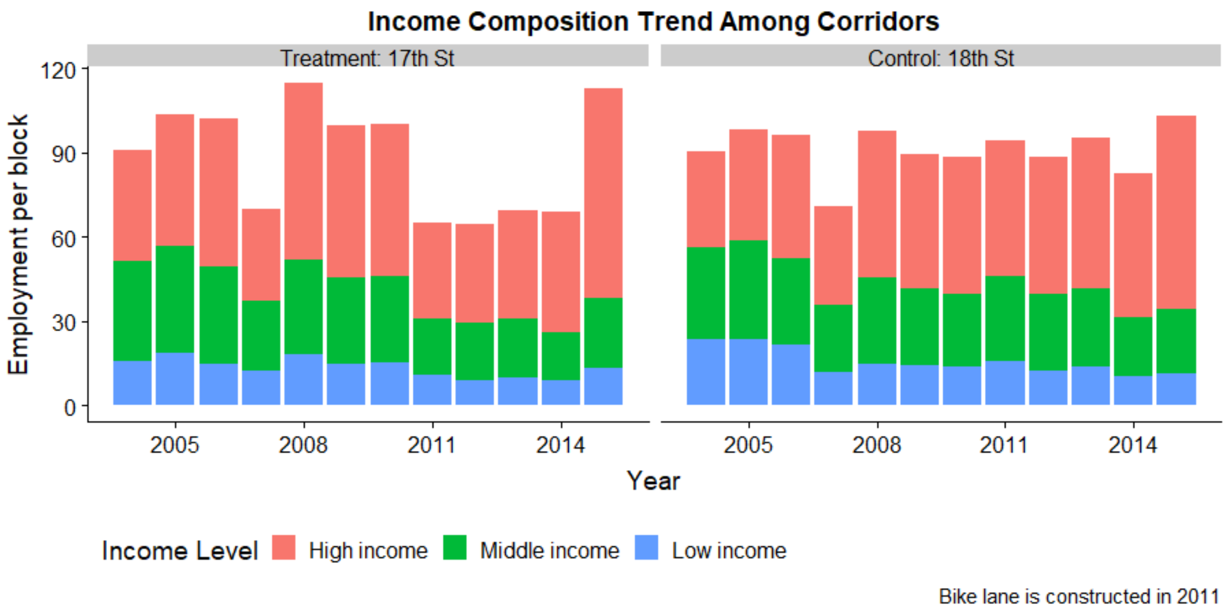


Figure 6-20. 17th Street Income Employment Level Composition Trend

6.2.3.2 Race

6.2.3.2.1 Employment

In terms of employment racial composition, the percentage of white employment had increased significantly, while the percentage of Asian employment decreased at the same time. We observed that the treatment corridor follows a similar trend as the employment racial composition trend on the control corridor and the city in general, although with slightly larger magnitudes.

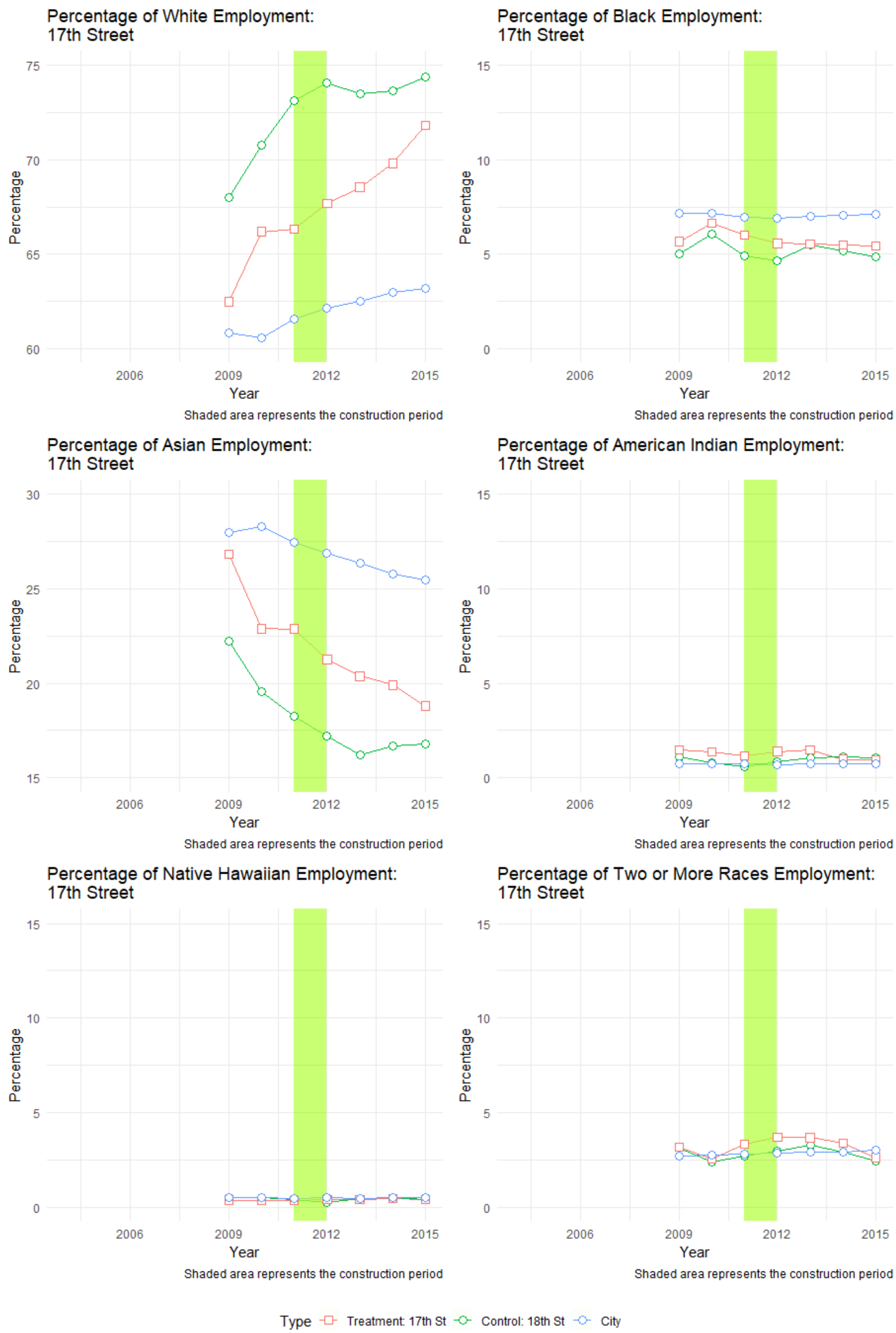


Figure 6-21. 17th Street Employment Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 6-30 summarizes the average percentage change of employment racial composition along the treatment and control corridors between 2011 and 2015. While some percentage changes appear large (such as those for Black, American Indian, Hawaiian and Two or more races), the actual change may be still small due to the small number of these racial groups in the starting year. This table shows very similar results to the above graphs, that the employment racial composition trend on the 17th Street treatment corridor is similar to the 18th Street control corridor and the city.

Table 6-30. 17th Street Employment Racial Composition Percentage Change (in percentage)

	Treatment: 17th St	Control: 18th St	City
White	2.07	0.44	0.65
Black	-2.34	-0.25	0.62
American Indian	-4.54	18.40	0.34
Asian	-4.45	-1.98	-1.79
Hawaiian	4.66	1.40	0.70
Two or more races	-5.30	-2.37	1.50

Note: These percentage changes are calculated as the average annual percentage change between 2011 and 2015.

6.2.3.2.2 Residents

The racial composition of the residents on the corridors shows a slightly different trend than the employment racial composition. The percentage of white residents on the treatment corridor decreased slightly, but increased on the control corridor and in the city as a whole. Similarly, the percentage of Asian residents increased on the treatment corridor, but decreased on the control corridor and in the city as a whole. This preliminary analysis of residential demographic changes does not provide evidence that the bike lane installation on 17th street led to displacement of groups of residents.

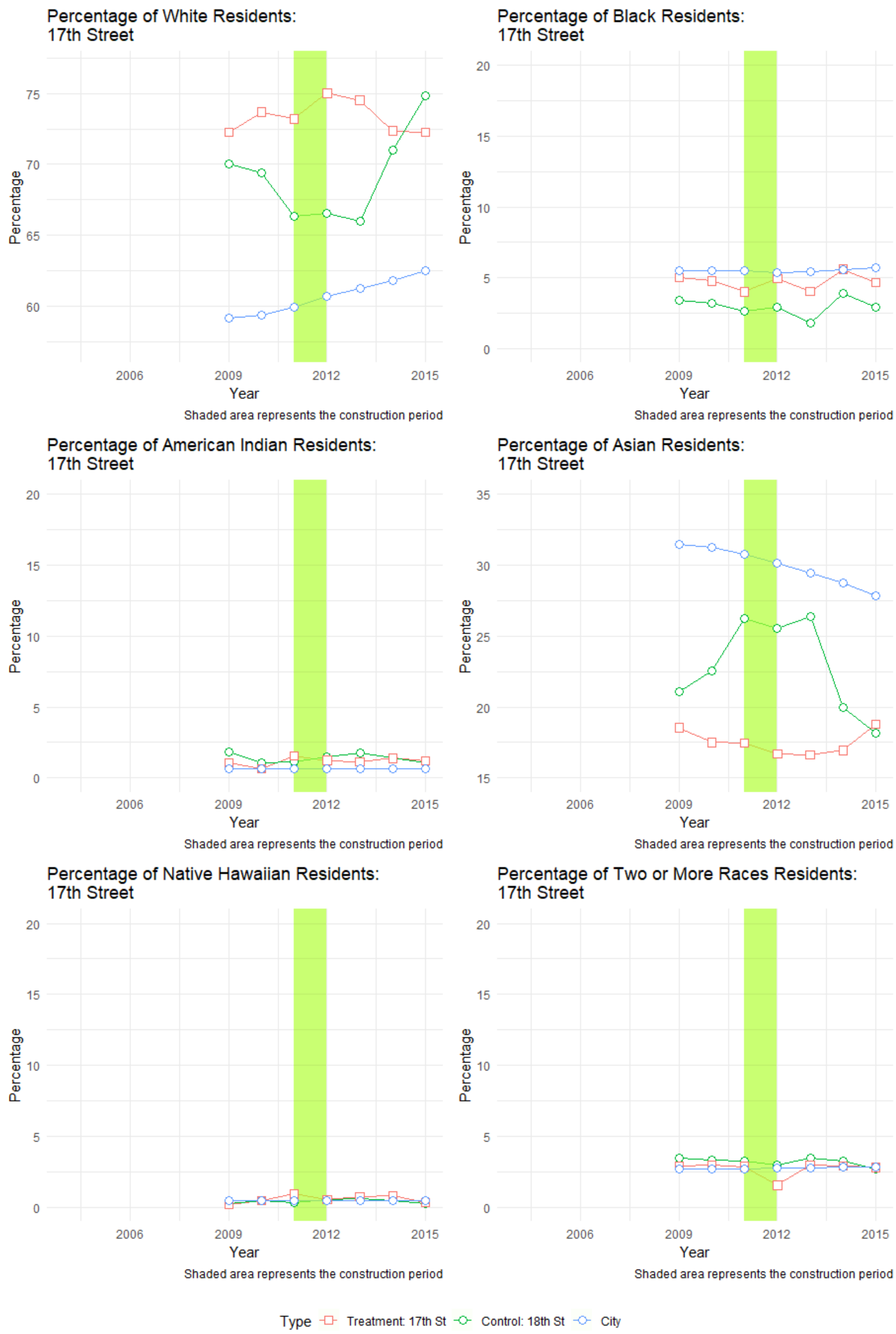


Figure 6-22. 17th Street Residents Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

From the table below, we found similar results as the above graphs, such that percentage of white decreased slightly and percentage of Asian increased slightly in the treatment corridor, which was opposite to the control corridor and city level. The percentage of black increased recently, while other races all decreased slightly. However, as we identified, these fluctuations might not be the actual change due to fusion techniques with LEHD data. The larger percentage change of each corridor for minorities is perhaps due to a smaller number of residents at the start year, 2011.

Table 6-31. 17th Street Residents Racial Composition Percentage Change (in percentage)

	Treatment: 17th St	**Control: 18th St**	**City**
White	-0.32	3.22	1.07
Black	4.03	2.66	0.78
American Indian	-5.59	-1.16	-0.05
Asian	1.91	-7.71	-2.35
Hawaiian	-16.61	-5.35	-1.00
Two or more races	-0.52	-4.66	1.43

Note: These percentage changes are calculated as the average annual percentage change between 2011 and 2015.

6.2.3.3 Education

6.2.3.3.1 Employment

In terms of education attainment, the selected corridors had fewer college-level employment, but more bachelor's or above employment. The treatment corridor generally had a similar trend as the control corridor and the city. During the time period of analysis, the percentage of bachelor's or above employment decreased while the other three categories all increased slightly. Again, we find no significant difference between employment education levels on the treatment corridor when compared to the control corridor, as is evidenced in both Figure 6-23 and Table 6-32.

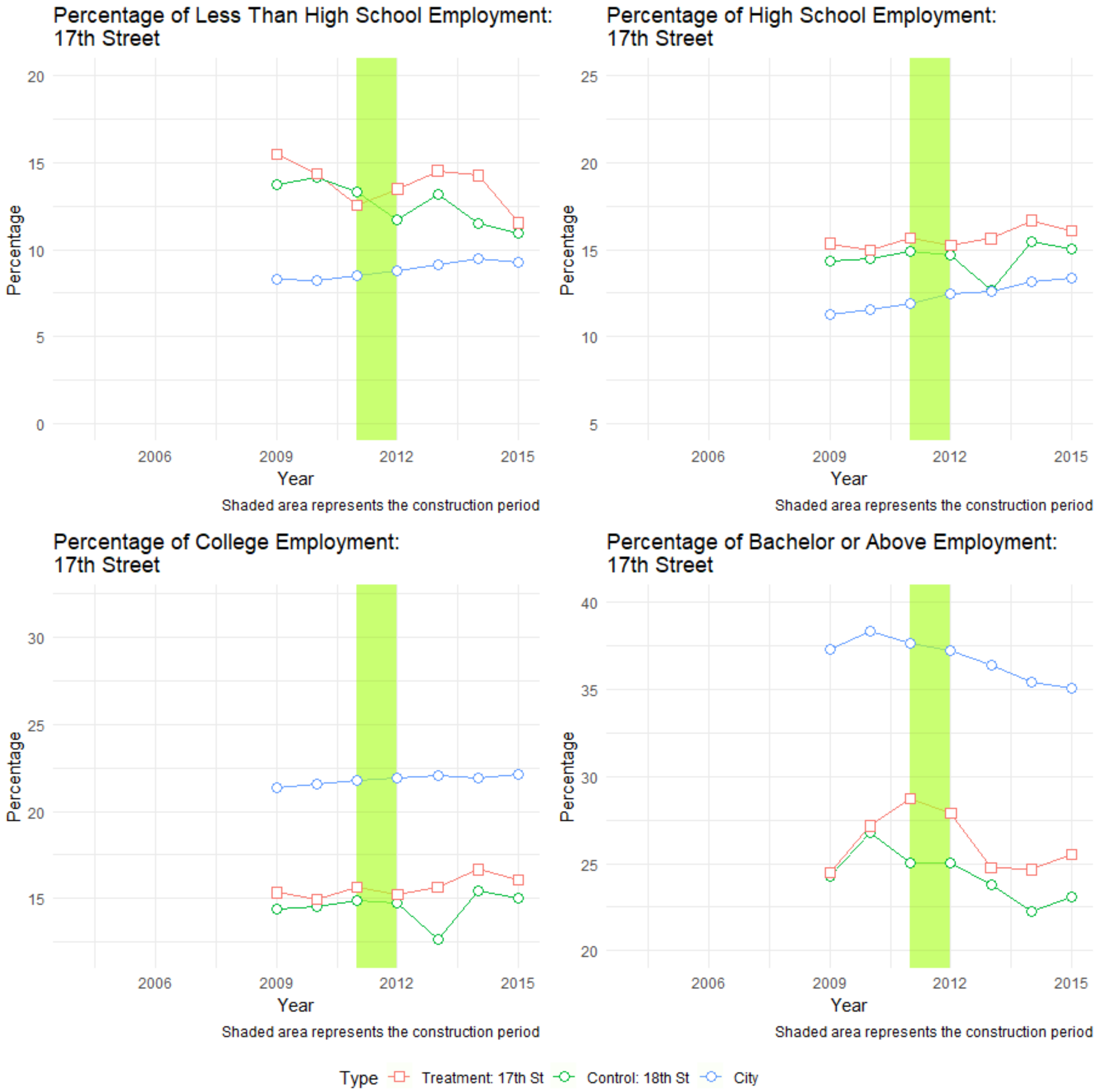


Figure 6-23. 17th Street Employment Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 6-32. 17th Street Employment Education Level Composition Percentage Change (in percentage)

	Treatment: 17th St	**Control: 18th St**	**City**
Less than high school	-2.00	-4.48	2.29
High school	0.65	0.19	3.08
College	0.65	0.19	0.36
Bachelor's or above	-2.77	-0.89	-1.73

Note: These percentage changes are calculated as the average annual percentage change between 2011 and 2015.

6.2.3.3.2 Residents

In terms of resident education levels, the trend shows much more fluctuation than the employment-education trend. We again observe that the treatment corridor generally follows a very similar pattern to the control corridor and the city. The average percentage change table (Table 6-33) demonstrates this as well.

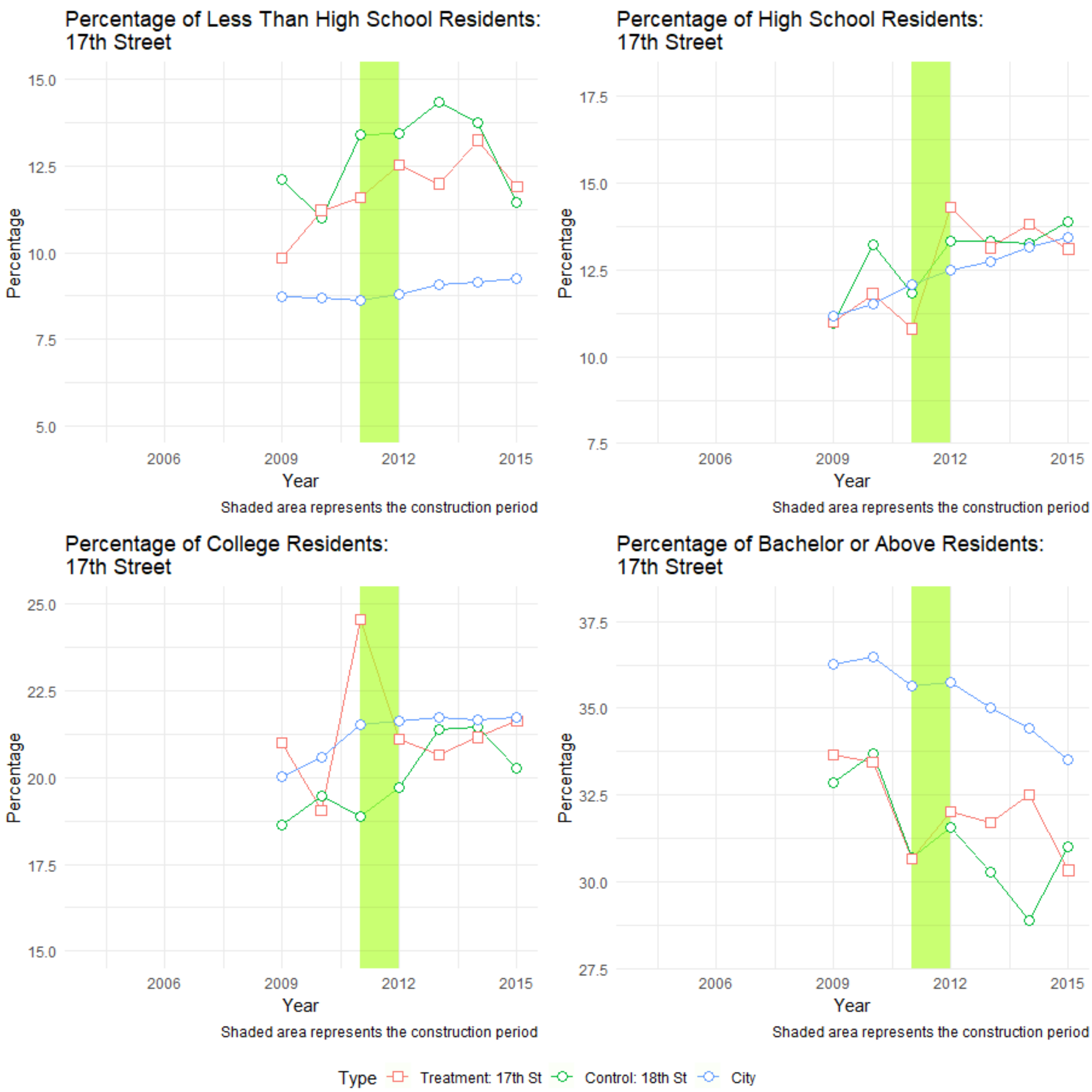


Figure 6-24. 17th Street Residents Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 6-33. 17th Street Residents Education Level Composition Percentage Change (in percentage)

	Treatment: 17th St	Control: 18th St	City
Less than high school	0.68	-3.65	1.82
High school	5.29	4.34	2.83
College	-2.98	1.83	0.27
Bachelor's or above	-0.26	-0.25	-1.48

Note: These percentage changes are calculated as the average annual percentage change between 2011 and 2015.

6.2.3.4 Gender

In terms of gender, the whole city experienced a decrease in female employment. However, both the 17th Street treatment corridor and the 18th Street control corridor experienced even sharper decreases in the percentage of female employment. Compared to employment gender composition, there were relatively fewer females who lived around the selected corridors, and we also observed a slight decreasing trend.

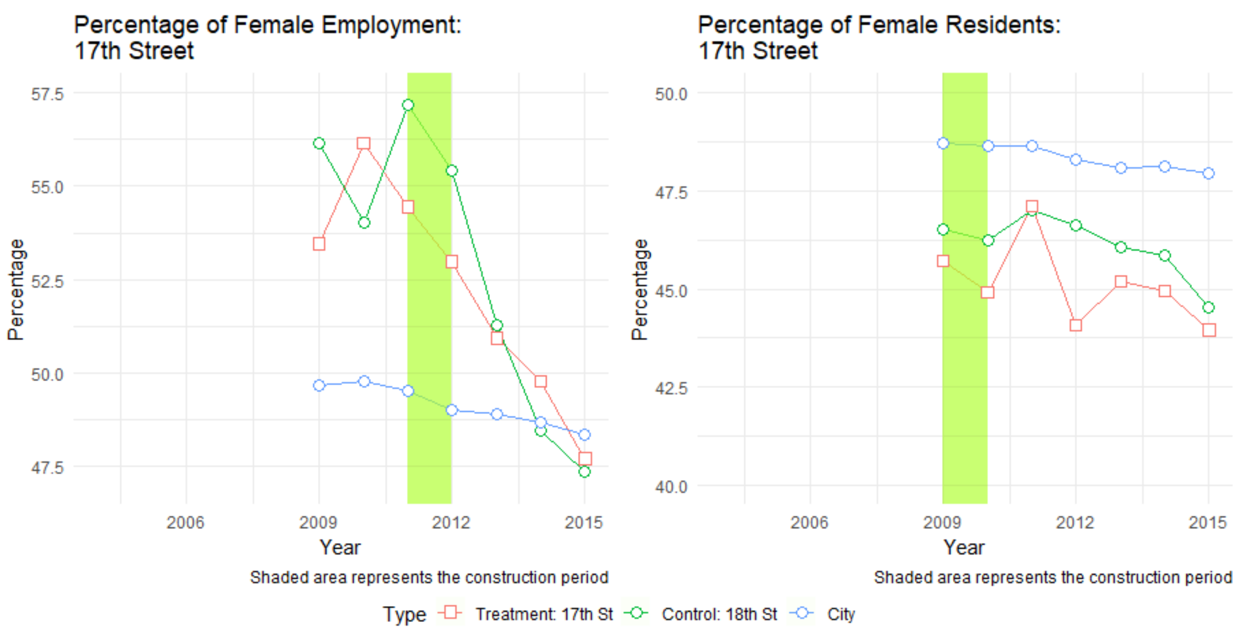


Figure 6-25. 17th Street Gender Composition Trend

In general, the construction of the bike lane on the 17th Street corridor did not appear to have caused any substantial demographic changes compared to the control corridor or the city as a whole. This preliminary distributional equity analysis of the demographic patterns along 17th Street should not be considered as a definitive indication that there are no equity or distributional concerns, and could benefit from additional research.

6.2.4 17th Street Corridor Summary

We used two different data sources, LEHD employment data and NETS employment and sales revenue data, to analyze the economic and equity impacts of street improvement on the 17th Street corridor. Each of these data sources was analyzed using the aggregated trend analysis, DID estimation and ITS estimation approaches, and we were able to conclude that:

- Analysis of the NETS and LEHD data showed slightly different results. We generally found that there were either positive impacts or non-significant impacts of the bike lane installation on retail service employment and sales on 17th Street, but negative or no impacts on food services.
- The environment justice indicators generally followed a similar trend between the treatment corridor, control corridor and the city. This indicates that the street improvement on the 17th Street corridor did not appear to have caused any substantial demographic changes compared to the control corridor or the city as a whole.

7.0 CASE EXPLORATION: MINNEAPOLIS

7.1 CENTRAL AVENUE

In 2012, bike lanes were installed on Central Avenue by reducing the width of travel lanes. University Avenue NE, which is parallel to the treatment corridor, was selected as the control corridor.

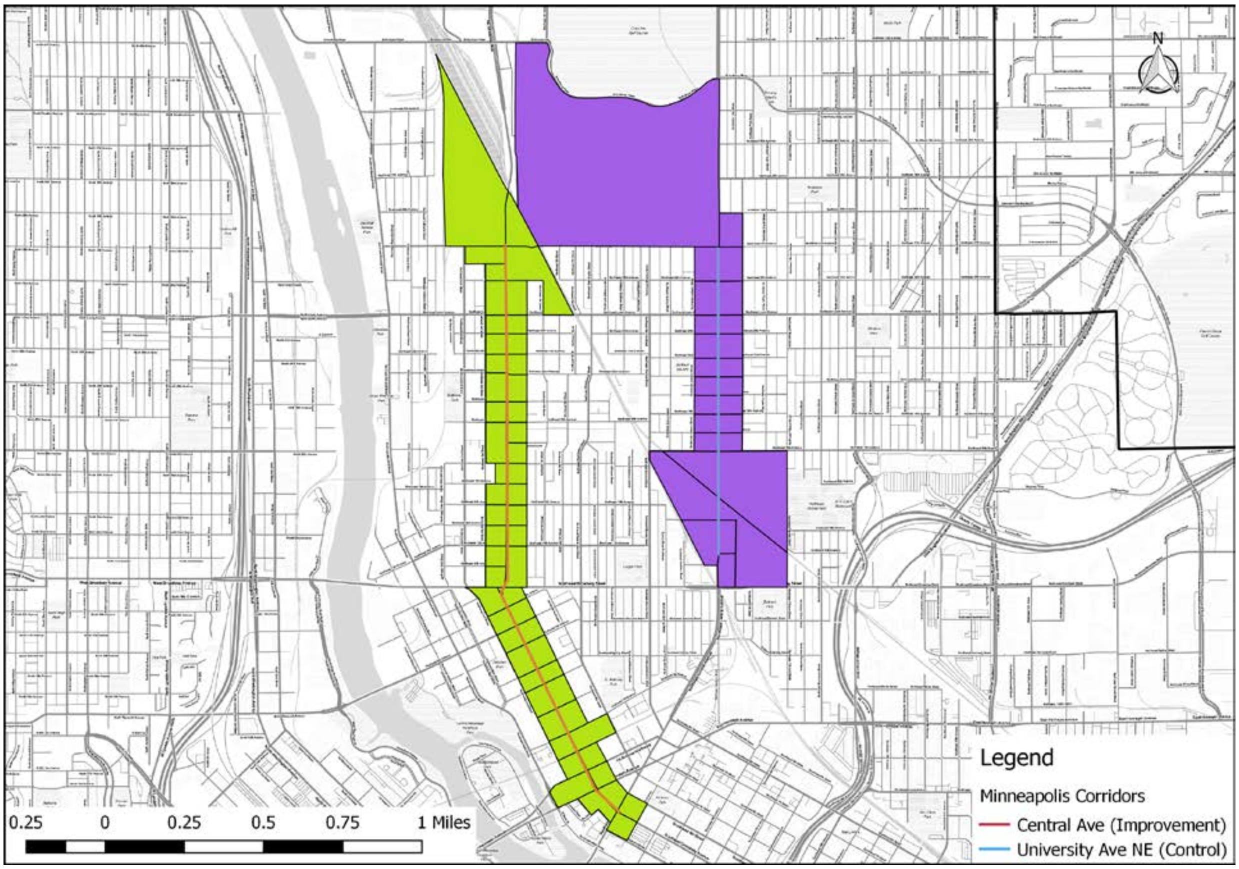


Figure 7-1. Minneapolis Central Avenue Corridor Map

7.1.1 Corridor Selection

Both Central Avenue and University Avenue NE are vital business corridors. As of 2011, the average business-related (retail and food and accommodation service) employment per block were 15 and 23 for the treatment and comparison corridors, respectively. The treatment corridor had slightly more retail jobs than the control corridor, but much less food and accommodation jobs. We further compared their retail employment density percentiles with the overall average per-block employment density in Minneapolis. The Central Avenue corridor has total and retail employment in the 65-70th and 75-80th percentiles of blocks in the city, respectively, which is slightly higher than the control corridor University Avenue. However, University Avenue has more food employment than Central Avenue. In general, the two corridors have similar levels of employment.

Table 7-1. Comparison of Business Jobs Per Block Percentiles Among Central Corridors

Corridor	Tot Emp	Retail Emp	Food Emp	Tot (%)	Retail (%)	Food (%)
Central Ave	77	10	5	65-70	65-70	50-55
University Ave	50	8	15	55-60	65-70	65-70

In addition, we compared business jobs as a percentage of all other service jobs for each block. On the treatment corridor, 35% of all service jobs are business jobs, and the number for the comparison corridor is 55%, which is higher than the treatment corridor. We further compared the average business job annual growth rates before the improvement completion, 2002-2011, for the two corridors. The annual growth rate on the treatment corridor was 3.0% compared to 4.4% on the comparison corridor. The t-test indicates no statistically significant differences at the 95% confidence interval between the two corridors. In terms of street characteristics, they are both local streets parallel to each other located in Northeast Minneapolis. The corridor selection process indicates that while there are some differences between the Central Avenue treatment corridor and the University Avenue NE control corridor, the University Avenue corridor is sufficiently similar to the treatment corridor as a control corridor.

Table 7-2. Study and Comparison Corridor Selection Criteria (Central Corridor)

<table>
<tr><td>Treatment Corridor</td><td colspan="2" rowspan="2">Indicator</td><td>Central</td></tr>
<tr><td>Control Corridor</td><td>University</td></tr>
<tr><td rowspan="3">Transportation/ Geography</td><td colspan="2">Geographic Proximity</td><td>□</td></tr>
<tr><td colspan="2">Street Classification</td><td>□</td></tr>
<tr><td colspan="2">Role in Street Network</td><td>□</td></tr>
<tr><td rowspan="5">Business Activity</td><td rowspan="2">Job Density Percentile</td><td>Retail</td><td>□</td></tr>
<tr><td>Food</td><td>□</td></tr>
<tr><td colspan="2">Share of Business Jobs</td><td>□</td></tr>
<tr><td rowspan="2">Employment Growth Rate</td><td>Retail</td><td>□</td></tr>
<tr><td>Food</td><td>□</td></tr>
</table>

7.1.2 Economic Outcome Analysis

7.1.2.1 LEHD Data

7.1.2.1.1 Aggregated Trend Analysis

Central Avenue shows a clear, positive retail employment trend post-construction that eventually outpaced the growth on the control corridor in 2015. Note that both corridors experienced positive employment trends during the post-construction period, and have more or less performed better than the city as a whole.

The food employment trend on Central Avenue is less obvious. The treatment corridor saw large increases in employment immediately following the post-construction period that had started to outpace food employment in the city, but the University Avenue control corridor has seen a consistently faster growth trend in the same sector since 2009. Given these results in the aggregated trend analysis of the LEHD data combined with the short post-construction period, we are unable to draw clear conclusions of the impact of the infrastructure on food employment here.

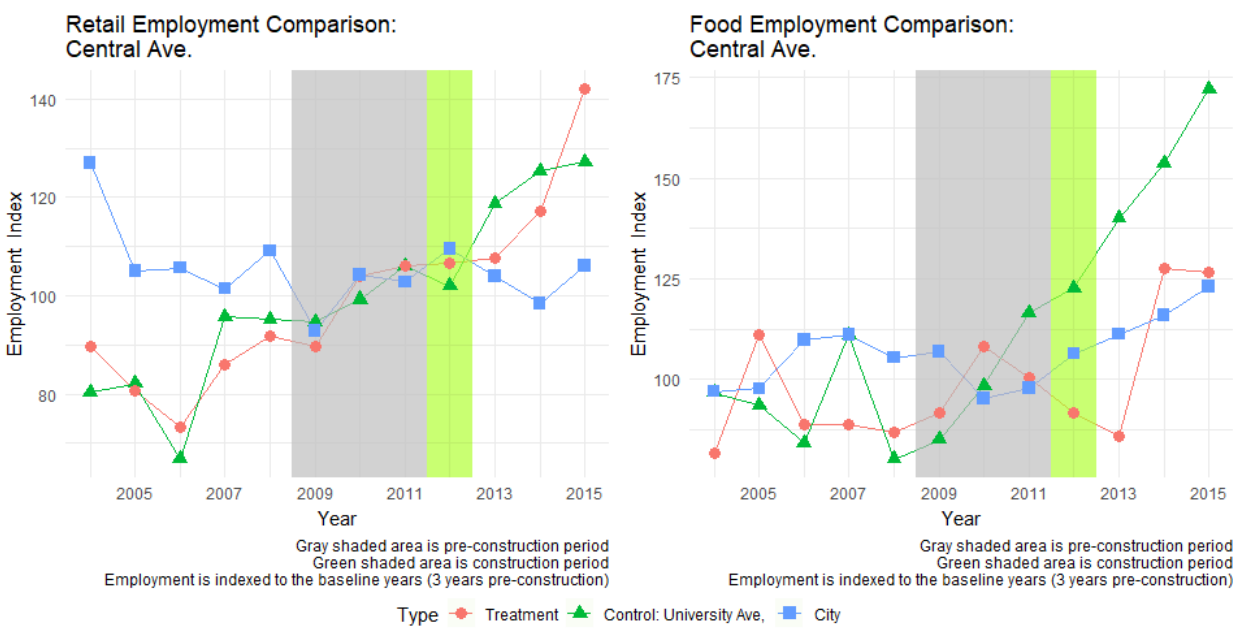


Figure 7-2. Aggregated Employment Trend of Central Corridor and Control Corridors (LEHD Data)

Table 7-3. Central Corridor Trend Analysis Summary Table (LEHD data)

	Retail						Food					
	Baseline		**Post-implementation**				**Baseline**		**Post-implementation**			
Area	**Base**	**Growth**	**1st Year**	**2nd Year**	**3rd Year**	**Avg.**	**Base**	**Growth**	**1st Year**	**2nd Year**	**3rd Year**	**Avg.**
LEHD: (employment)												
Treatment	189	8.96%	7.94%	8.82%	21.17%	12.64%	103	5.44%	-14.56%	48.86%	-0.76%	11.18%
Control: University	222	5.79%	18.47%	5.70%	1.44%	8.54%	393	17.11%	39.95%	9.82%	12.09%	20.62%

[1] Baseline is defined as the average of previous three years before construction year;
[2] Pre-growth rate is defined as average of baseline annual growth rate;
[3] 1st year growth rate is defined as the growth rate of the year after construction compared to baseline.

7.1.2.1.2 Difference-in-Difference (DID) Analysis

DID analysis of LEHD data on the Central Avenue treatment corridor showed a significant and negative impact on food employment, and a non-significant impact on retail employment. These results are indicative of the drop-in food employment that we observed through our aggregated trend analysis of the same data, and the more robust growth in employment on the control corridor over time.

Table 7-4. Central Corridor DID Regression Result (LEHD Data)

	Dependent variable:		
	Retail Emp.	Food Emp.	'Business' Emp.
Type:treatment	-28.111^{**}	-291.111^{***}	-319.222^{***}
	(11.756)	(20.594)	(28.135)
Pre/post	71.889^{***}	222.444^{***}	294.333^{***}
	(16.625)	(29.125)	(39.789)
DID estimator: treatment	-14.556	-202.889^{***}	-217.444^{***}
	(23.511)	(41.189)	(56.271)
Constant	202.444^{***}	387.889^{***}	590.333^{***}
	(8.312)	(14.562)	(19.895)
Observations	24	24	24
R^2	0.668	0.955	0.936
Adjusted R^2	0.619	0.948	0.927
Residual Std. Error (df = 20)	24.937	43.687	59.684
F Statistic (df = 3; 20)	13.439^{***}	142.041^{***}	97.844^{***}
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$		

7.1.2.1.3 Interrupted Time Series (ITS) Analysis

ITS analysis of the LEHD data on Central Avenue also showed mixed results, but this may be due to the limited number of data points after construction that is available. According to this model specification, Central Avenue retail employment saw a negative, statistically significant drop in employment level after the treatment, but there is a positive slope signaling an overall positive growth trend. Again, combining these results with the aggregated trend analysis of employment, it becomes clear that Central Avenue experienced lower retail employment post-construction but greater growth (slope), indicating a positive trajectory. There is a similar trend in food services employment, indicating that Central Avenue saw a lower level of food employment post-construction but with greater growth rate (slope).

Table 7-5. Central Corridor ITS Regression Results (LEHD Data)

	Dependent variable		
	Retail Emp.	Food Emp.	'Business' Emp.
Yearly trend	6.583***	0.833	7.417***
	(1.708)	(1.531)	(2.145)
Level change	-267.250**	-207.278*	-474.528***
	(103.616)	(92.874)	(130.136)
Slope change	25.917**	20.167**	46.083***
	(9.508)	(8.522)	(11.941)
Constant	141.417***	92.611***	234.028***
	(9.610)	(8.613)	(12.069)
Observations	12	12	12
R^2	0.896	0.613	0.910
Adjusted R^2	0.858	0.468	0.876
Residual Std. Error (df = 8)	13.228	11.856	16.613
F Statistic (df = 3; 8)	23.069***	4.231**	26.965***
Note:	*p<0.1; **p<0.05; ***p<0.01		

7.1.2.2 Sales Tax Data

7.1.2.2.1 Aggregated Trend Analysis

The aggregated trend analysis of sales tax receipts on Central Avenue indicates some positive impacts of the bike lane installation on business vitality. While Central Avenue's sales receipts grew in both the retail and restaurant sectors, the positive growth trends for both industries start either before or at the beginning of the construction period. In particular, retail sales revenue appears to grow over the time period of analysis, while retail sales revenue on the control corridor is dropping. The rate of change in growth, though, in restaurant receipts on the treatment corridor appears to quickly accelerate post-construction. While not definitive, this acceleration in growth in the food industry hints at potential positive impacts that our econometric models will explain more clearly.

The indexed value plots bring the differences between growth rates between the treatment and control corridors into stark relief. Central Avenue has fared much better over the course of the study period, exhibiting robust growth in both retail and restaurant sales. The post-construction growth bump is especially apparent in the restaurant sales indexed plot (Figure 7-4). University Avenue's flattened growth in both restaurant and retail sales is especially striking in comparison to the consistent growth on the improved corridor.

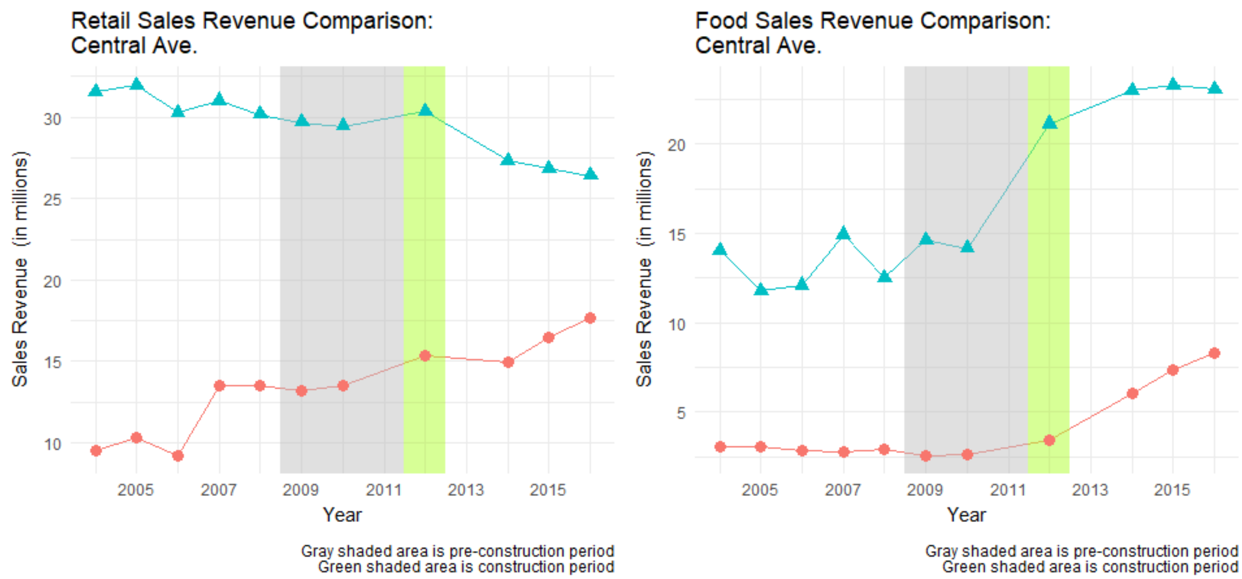


Figure 7-3. Aggregated Retail Sales Trend of Central Corridor and Control Corridors (Retail Sales Tax Data)

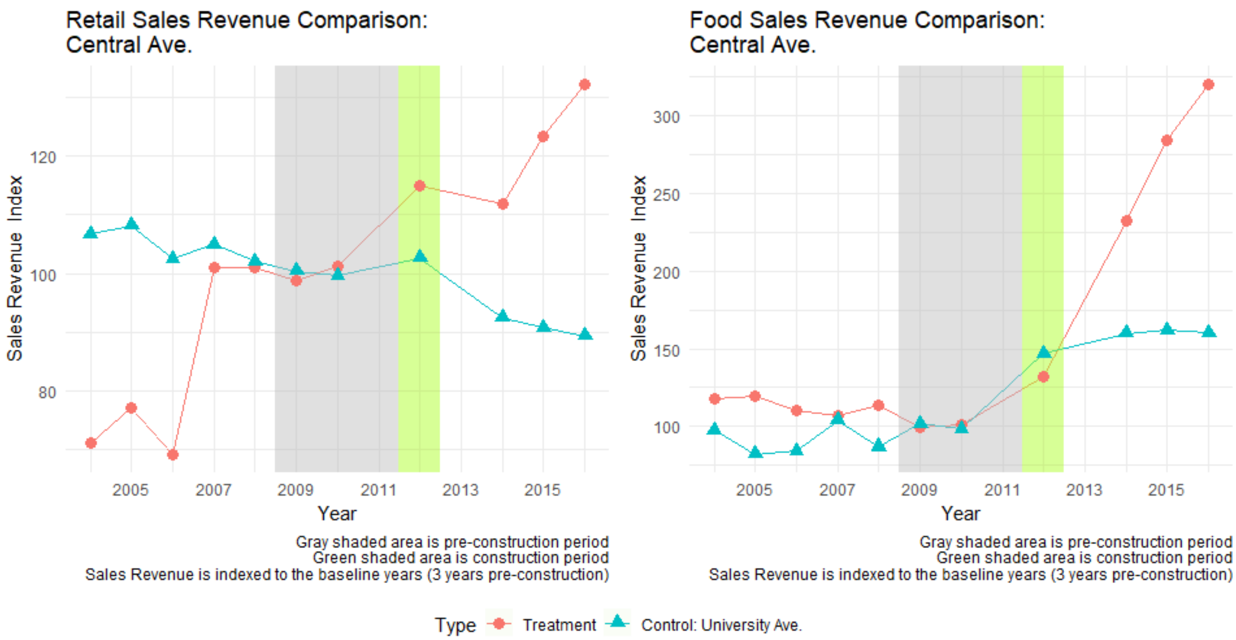


Figure 7-4. Indexed Aggregated Retail Sales Trend of Central Corridor and Control Corridors (Retail Sales Tax Data)

7.1.2.2.2 Difference-in-Difference (DID) Analysis

The DID analysis of sales tax data on Central Avenue shows mixed results of the street improvement. The estimated difference coefficient for restaurant sales is negative and significant while the coefficient for retail sales is positive and significant. Overall, this model specification implies that an additional $7 million in retail sales tax receipts and a loss of $5.7 million in restaurant receipts may be attributed to the street improvement. This shift possibly indicates that the new infrastructure construction on Central Avenue contributed to an industrial shift from food services establishments to retail along this corridor. However, the analysis is unable to provide us with the reason underlying this shift, and an examination of the context of the street improvement or other factors on the corridor may be needed.

Table 7-6. Central Corridor DID Regression Result (Retail Sales Tax Data)

	Dependent variable	
	Restaurant	Retail
	Restaurant Sales	Retail Sales
Type:treatment	-10,619,800.000***	-18,768,572.000***
	(649,782.100)	(838,441.000)
Pre/post	9,179,680.000***	-2,866,845.000***
	(761,937.100)	(983,159.300)
DID estimator: treatment	-5,752,489.000***	7,168,875.000***

	(1,077,542.000)	(1,390,397.000)
Constant	13,453,798.000***	30,588,644.000***
	(459,465.300)	(592,867.400)
Observations	22	22
R^2	0.977	0.971
Adjusted R^2	0.973	0.967
Residual Std. Error (df = 18)	1,215,631.000	1,568,580.000
F Statistic (df = 3; 18)	255.593***	203.843***
Note:	*p<0.1; **p<0.05; ***p<0.01	

7.1.2.2.3 Interrupted Timer Series (ITS) Analysis

The sales tax ITS analysis shows the ts_year:pre_post term is significant and positive for restaurant sales, but non-significant for retail sales. Also note the large negative and significant pre-post term for restaurant sales, which is similar to our analysis of the LEHD employment data that shows there was a drop in activities in the food services industry after the construction, but this lower level is coupled with a positive growth trajectory. The impact of the street improvement on Central Avenue should become clearer as additional data points become available in the future.

Table 7-7. Central Corridor ITS Regression Result (Retail Sales Tax Data)

	Dependent variable:	
	Restaurant	Retail
	Restaurant Sales	Retail Sales
Yearly trend	-81,086.390**	791,191.500***
	(24,587.040)	(212,880.600)
Level change	-10,816,427.000***	1,015,786.000
	(511,032.100)	(4,424,641.000)
Slope change	1,318,355.000***	-217,768.500
	(50,388.440)	(436,275.500)
Constant	3,158,344.000***	8,655,305.000***
	(109,956.600)	(952,031.200)
Observations	11	11
R^2	0.997	0.884
Adjusted R^2	0.996	0.834
Residual Std. Error (df = 7)	130,102.400	1,126,459.000
F Statistic (df = 3; 7)	856.183***	17.736***
Note:	*p<0.1; **p<0.05; ***p<0.01	

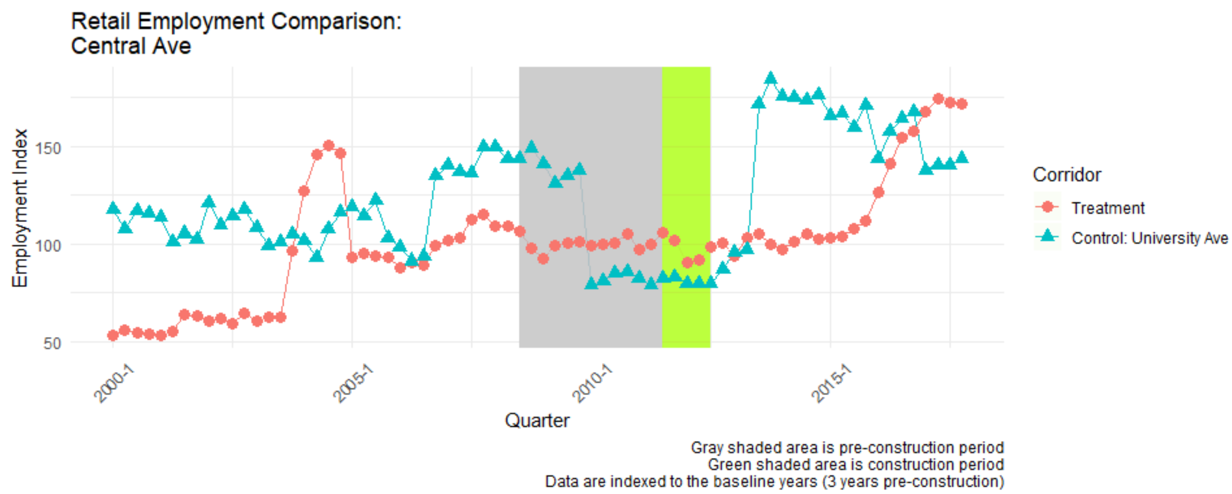
7.1.2.3 QCEW Data

7.1.2.3.1 Aggregated Trend Analysis

Central Avenue retail employment was highly volatile in the early part of the 2000s, maintaining a level of around 200 jobs immediately before and through the recession. In the past few years, retail employment along this corridor has seen fairly dramatic growth. University Avenue, on the other hand, lost a large number of jobs during the same period, but saw a spike in employment around 2012. The total wages paid on the two corridors largely mirror the employment levels directly. The aggregated trend analysis of the QCEW data indicate that there is not an immediately apparent connection between the street improvement and employment or wage levels on Central Avenue.

Figure 7-5. Aggregated Employment and Wages Trend of Central Corridor and Control Corridors (QCEW Data)

The indexed plots show dramatic growth on both Central and University avenues over the past decade and a half with respect to both retail employment and wages. One detail to note is that the Central Avenue treatment corridor continues on its positive trajectory for both wages and employment in the last few years, and ultimately surpasses the much more volatile University Avenue control corridor in terms of growth.



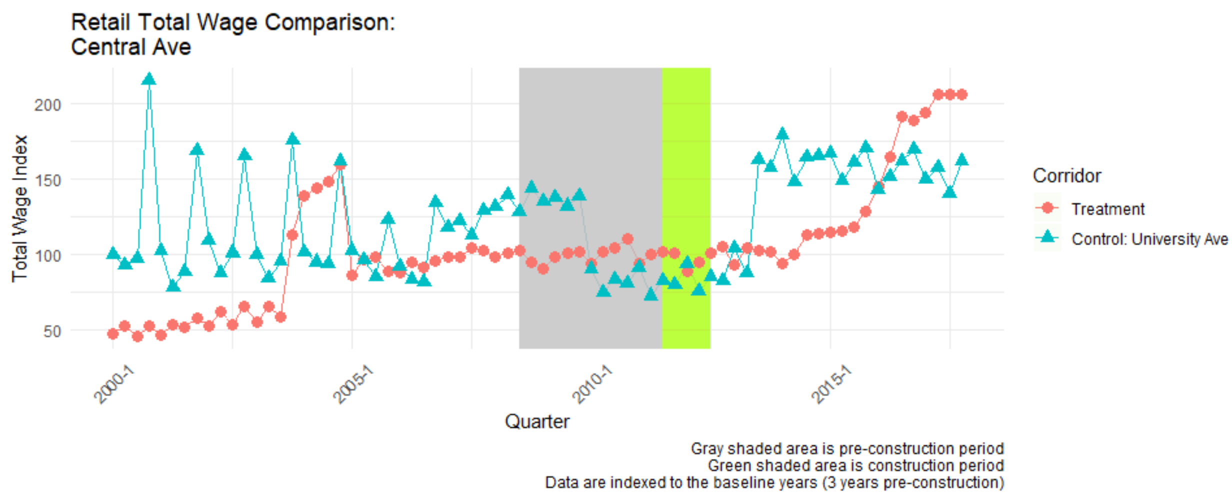


Figure 7-6. Indexed Aggregated Employment and Wages Trend of Central Corridor and Control Corridors (QCEW Data)

Table 7-8. Central Corridor Trend Analysis Summary Table (QCEW Data)

	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
Area	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
QCEW: (employment)												
Treatment	209	1.50%	0.64%	0.99%	4.98%	2.20%	-	-	-	-	-	-
Control: University	152	-20.28%	37.01 %	27.85 %	-5.35%	19.84 %	-	-	-	-	-	-

[1] Baseline is defined as the average of previous three years before construction year;
[2] Pre-growth rate is defined as average of baseline annual growth rate;
[3] 1st year growth rate is defined as the growth rate of the year after construction compared to baseline.

7.1.2.3.2 Difference-in-Difference (DID) Analysis

The QCEW DID estimates for wages and employment both returned non-significant results. This makes intuitive sense when examining the employment and wage figures from the aggregated trend analysis. While there appears to be growth in wages and employment, it is not clear that growth in either economic indicator can be attributed to the construction of the bike lane.

Table 7-9. Central Corridor DID Regression Results (QCEW Data)

	Dependent variable:	
	avg_emp Average Employment	total_wages Total Wages
Pre/post	61.785***	530,745.000***
	(12.262)	(90,360.640)
Type: control	-18.437*	59,994.460
	(10.012)	(73,779.150)
DID estimator: control	-15.368	-226,026.800*
	(17.341)	(127,789.200)
Constant	189.424***	1,069,647.000***
	(7.079)	(52,169.740)
Observations	144	144
R^2	0.255	0.247
Adjusted R^2	0.239	0.231
Residual Std. Error (df = 140)	49.047	361,442.600
F Statistic (df = 3; 140)	16.009***	15.312***
Note:	*p<0.1; **p<0.05; ***p<0.01	

7.1.2.3.3 Interrupted Time Series (ITS) Analysis

The QCEW ITS models for Central Avenue offer a mixed set of conclusions. For employment, the ITS has a negative and significant result for the level change but a non-significant result for a slope change. The wage model, on the other hand, shows a negative and significant result for the pre-post term and a positive and significant result for the ts_year:pre_post term, showing a negative change in level but positive change in slope post-construction.

Table 7-10. Central Corridor ITS Regression Results (QCEW Data)

	Dependent variable:	
	avg_emp Average Employment	tot_wages Total Wages
Yearly trend	8.968**	212,501.100**
	(3.442)	(89,189.410)
Level change	-339.805**	-11,827,929.000***
	(145.390)	(3,767,176.000)
Slope change	22.129*	830,234.400***
	(10.424)	(270,104.500)
Constant	140.098***	3,109,830.000***
	(22.352)	(579,159.100)
Observations	18	18
R^2	0.648	0.732
Adjusted R^2	0.573	0.675
Residual Std. Error (df = 14)	41.162	1,066,550.000
F Statistic (df = 3; 14)	8.596***	12.751***
Note:	*p<0.1; **p<0.05; ***p<0.01	

7.1.2.4 NETS Data

7.1.2.4.1 Aggregated Trend Analysis

The following tables and figures present the employment and sales change before and after street improvement on Central Avenue using the NETS dataset. As described previously in the data section, economic data from two types of industry categories are presented here: Type I includes all retail and food service establishments on the abutting blocks of the corridor, and Type II includes a refined subset of establishments directly facing the corridor (block-face establishments). Since the treatment and control corridors in this particular scenario are neighboring streets parallel to each other, Type I block-level data on the two corridors may include overlapping establishments.

In terms of the Type I industry (directly corresponding to LEHD industry categories), the treatment corridor retail employment and sales increased significantly right after the construction year, but declined after that. Employment and sales in the food service sector show persistent growth after the bike lane installation. In addition, the Central Avenue treatment corridor generally followed a similar trend as the city in both retail and food service sectors. However, the University Avenue control corridor performed even better than the street improvement corridor, with continuous growth in employment and sales of both sectors. In particular, much of the increase in the retail sector on University Avenue was due to increases in the number of retail establishments (Figure 7-7 B and Figure 7-8 B).

Table 7-11. Central Avenue Corridor Aggregated Employment Changes Post-Improvement (NETS Data, Industry Type I)

Corridor	Baseline employment (2012)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Central Ave	187	147	3.74%	19.04%	-8.25%	2.85%	-6.74%	5.00%
University Way	203	498	-8.37%	21.88%	1.61%	2.31%	3.70%	-1.77%
Minneapolis	67,014	41,262	-1.33%	1.84%	-3.35%	0.11%	-3.65%	0.97%

Table 7-12. Central Avenue Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, Industry Type I)

Corridor	Baseline sales (2012)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Central Ave	16,528,100	4,549,500	6.42%	18.63%	-8.29%	2.65%	-7.19%	5.57%
University Way	32,202,458	18,415,000	6.84%	19.84%	0.04%	1.28%	1.57%	-0.38%
Minneapolis	9,855,057,021	1,341,668,730	-3.42%	2.94%	-1.41%	0.74%	-2.98%	0.60%

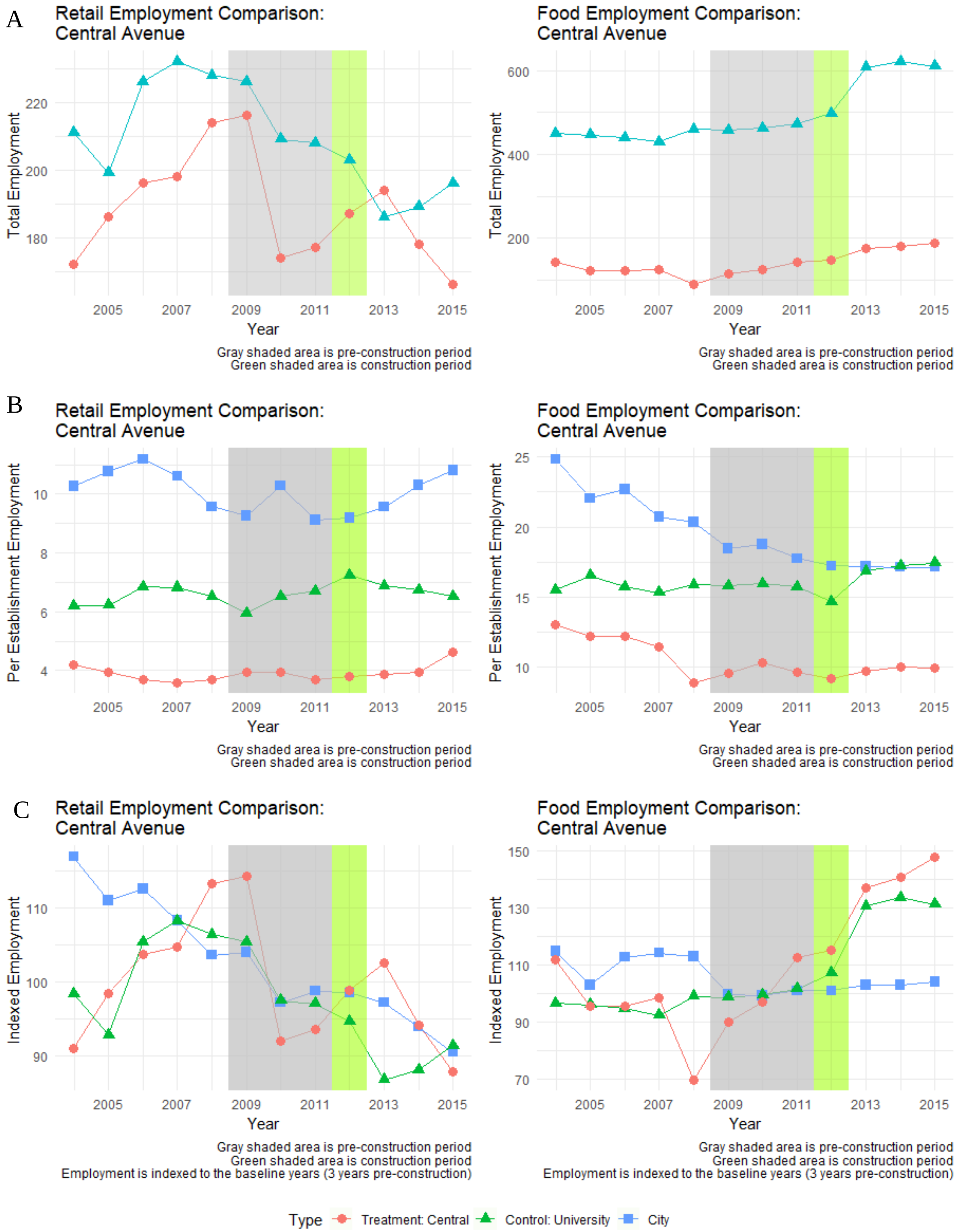


Figure 7-7. Aggregated Employment Trend Central Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type I

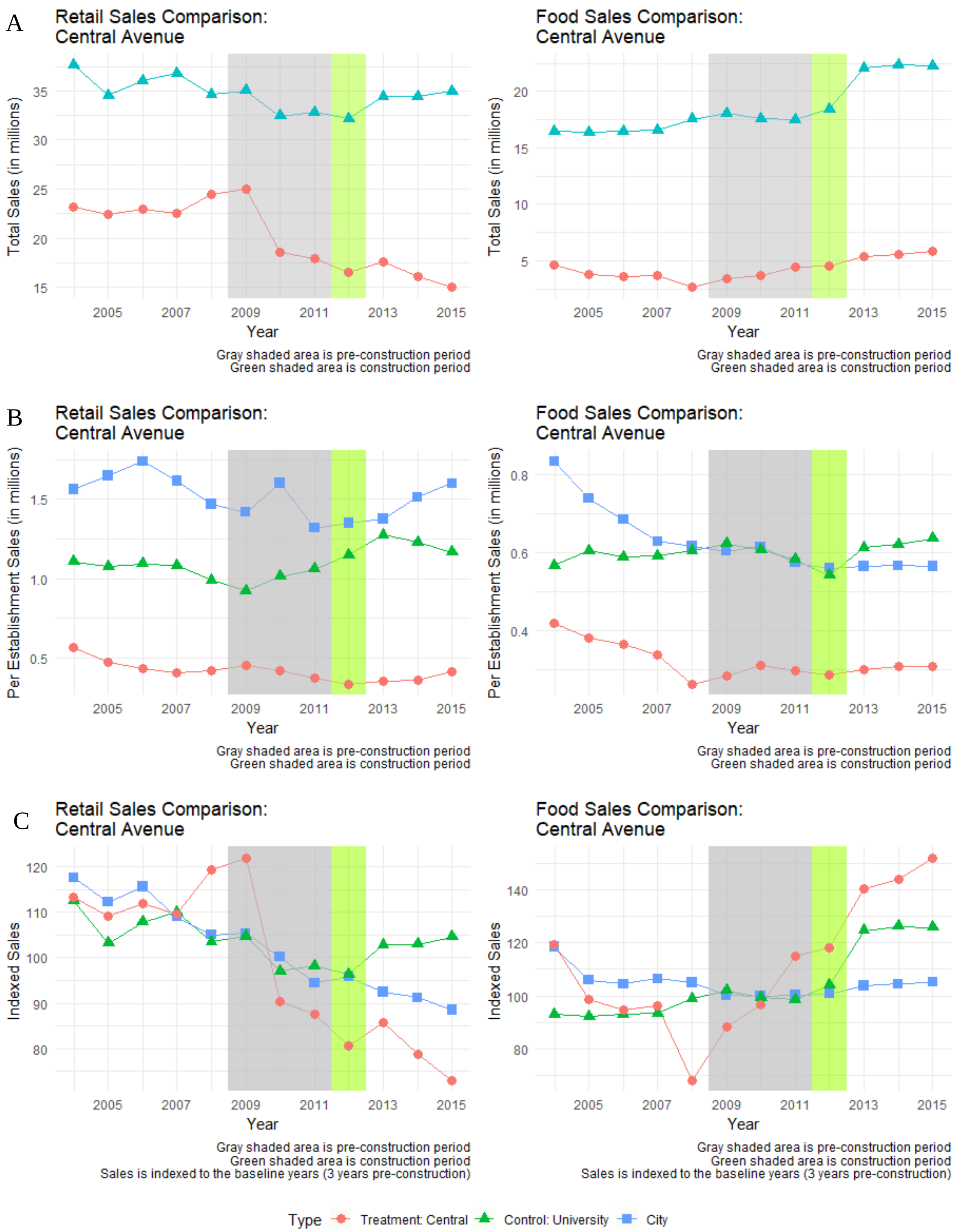


Figure 7-8. Aggregated Sales Trend of Central Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type I

Within the more refined Type II-industry categories, employment and sales trends generally followed the same trend as the Type I-industry categories. Retail service employment and sales on the treatment corridor increased right after the construction year, but decreased afterwards. Food service employment and sales on the treatment corridor, on the other hand, experienced sharp increases that were similar to the control corridor and were much better than the city trends.

Table 7-13. Central Avenue Corridor Aggregated Employment Changes Post-Improvement (NETS Data, Industry Type I)

Corridor	Baseline employment (2012)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Central Ave	116	133	3.45%	21.05%	-5.83%	5.59%	-7.08%	5.29%
University Way	119	299	-15.97%	32.12%	3.00%	1.51%	9.71%	0.25%
Minneapolis	50,167	39,600	-1.76%	1.46%	-3.92%	-0.04%	-3.88%	1.11%

Table 7-14. Central Avenue Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, Industry Type I)

Corridor	Baseline sales (2012)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Central Ave	10,846,900	4,052,100	5.27%	20.63%	-6.24%	6.93%	-6.15%	5.94%
University Way	32,202,458	18,415,000	0.29%	27.26%	0.02%	1.16%	4.07%	1.33%
Minneapolis	6,211,215,063	1,283,303,030	-1.49%	2.64%	-2.39%	0.47%	-2.36%	0.84%

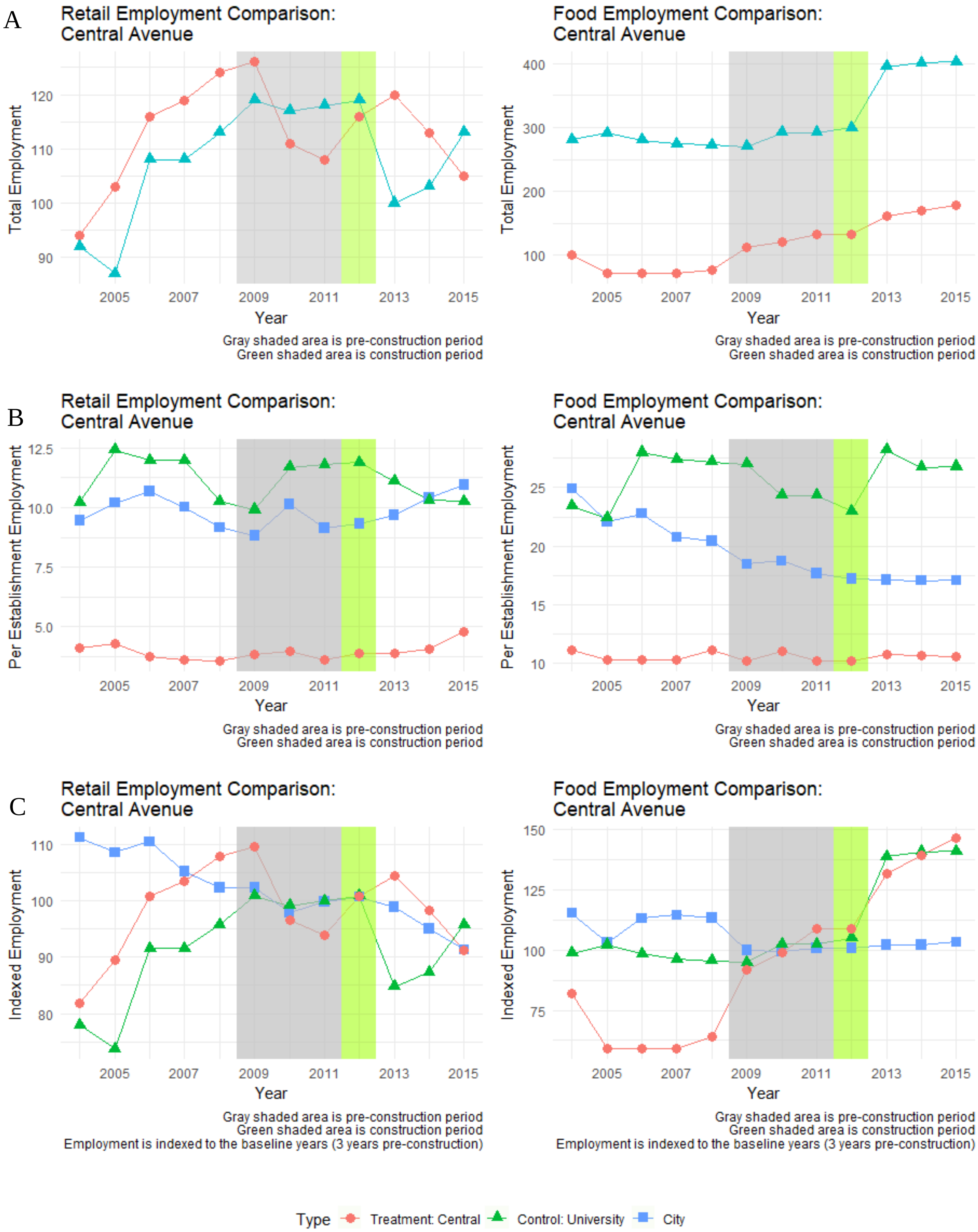


Figure 7-9. Aggregated Employment Trend of Central Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type II

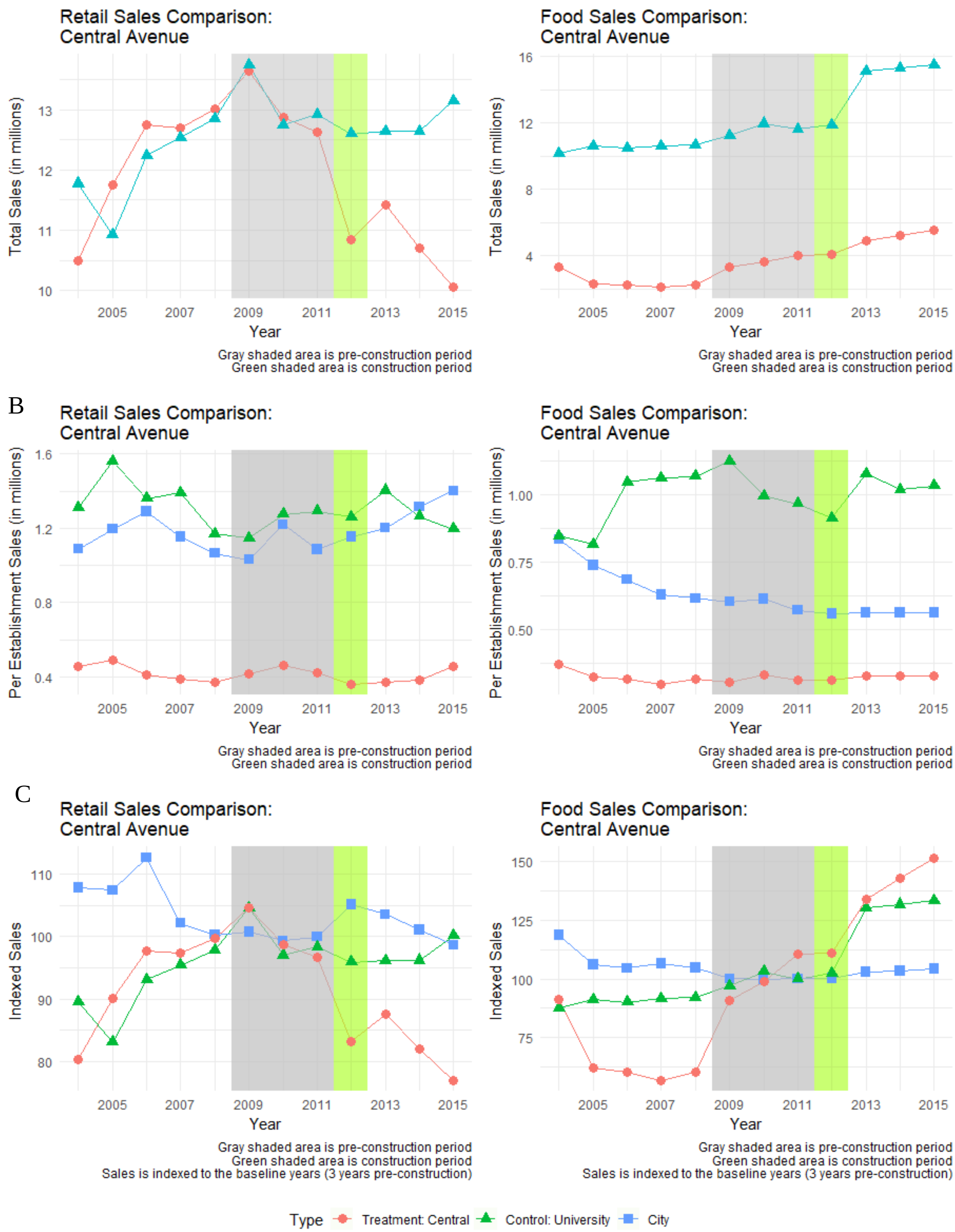


Figure 7-10. Aggregated Sales Trend of Central Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type II

7.1.2.4.2 Difference-in-Difference (DID) Analysis

DID analysis of the NETS dataset are presented below. Since the NETS dataset has longer historical data, we chose to use the data between 2005 and 2015 for our analysis to maintain consistency, and limit this analysis to only the Type II establishments as these are the businesses that directly face the street improvement corridor. The results indicate that there was no apparent impact of bike lane installation on employment change on the improved Central Avenue corridor, but there was negative impact on retail sales, with $2,219,250 less in retail sales compared to the control corridor.

Table 7-15. Central Avenue Corridor DID Regression Result (NETS Data)

	Dependent variable:					
		Employment			Sales	
	Retail	Food	Business	Retail	Food	Business
Type Control	-4.750	186.500***	181.750***	301,850.000	8,405,013.000***	8,706,863.000***
	(3.244)	(17.485)	(16.232)	(340,853.700)	(605,238.400)	(598,053.000)
Pre/post	-8.500	64.250**	55.750**	-2,106,025.000***	2,087,700.000**	-18,325.000
	(5.129)	(27.646)	(25.665)	(538,937.000)	(956,965.900)	(945,604.800)
DID estimator control	3.750	40.500	44.250	2,219,250.000**	1,609,758.000	3,829,008.000**
	(7.254)	(39.097)	(36.296)	(762,172.000)	(1,353,354.000)	(1,337,287.000)
Constant	117.500***	110.250***	227.750***	12,483,175.000***	3,295,200.000***	15,778,375.000***
	(2.294)	(12.364)	(11.478)	(241,020.000)	(427,968.200)	(422,887.300)
Observations	20	20	20	20	20	20
R^2	0.256	0.916	0.923	0.571	0.946	0.954
Adjusted R^2	0.116	0.900	0.909	0.491	0.936	0.945
Resid.Std. Error (df = 16)	6.488	34.970	32.464	681,707.400	1,210,477.000	1,196,106.000
F Statistic (df = 3; 16)	1.835	58.198***	64.084***	7.099***	93.191***	109.947***
Note:	*p<0.1; ** **p<0.05;** *** p<0.01					

7.1.2.4.3 Interrupted Time Series (ITS) Analysis

Similar to DID analysis, we only conducted the ITS analysis on Type II block-face level establishments using NETS data, and chose to utilize only the data between 2005 and 2015 for this analysis. However, contrary to results from the DID analysis, the ITS analysis indicates there was no particular impact of the bike lanes installation on retail and food for both employment and sales.

Table 7-16. Central Avenue Corridor ITS Regression Result (NETS Data)

	Dependent variable:					
	Employment			Sales		
	Retail	Food	Business	Retail	Food	Business
Yearly trend	-0.595	13.119***	12.524***	-244,721.400*	411,333.300***	166,611.900
	(0.986)	(1.361)	(1.533)	(112,810.600)	(47,093.520)	(134,348.800)
Level change	79.631	46.024	125.655	3,876,036.000	1,184,867.000	5,060,902.000
	(104.270)	(143.908)	(162.041)	(11,926,751.000)	(4,978,901.000)	(14,203,856.000)
Slope change	-7.405	-4.119	-11.524	-413,778.600	-100,333.300	-514,111.900
	(9.093)	(12.549)	(14.131)	(1,040,062.000)	(434,180.800)	(1,238,635.000)
Constant	121.369***	24.976**	146.345***	14,073,864.000***	621,533.300	14,695,398.000***
	(6.797)	(9.381)	(10.563)	(777,493.200)	(324,569.700)	(925,935.500)
Observations	10	10	10	10	10	10
R^2	0.399	0.967	0.951	0.754	0.962	0.212
Adjusted R^2	0.098	0.951	0.927	0.631	0.943	-0.181
Residual Std. Error (df = 6)	6.392	8.821	9.933	731,096.100	305,200.900	870,680.000
F Statistic (df = 3; 6)	1.326	59.430***	39.059***	6.129**	50.558***	0.539
Note:	**p<0.1; ** **p<0.05;** **** p<0.01					

7.1.3 Distributional Analysis

The distributional analysis aims to track the demographic changes of residents along the treatment corridor, control corridors, and the city as a whole before and after the bike lane installation to examine any potential equity outcomes of the bike lane installation on the Central Avenue corridor. This analysis is conducted using the LEHD dataset, where income indicators are available for a longer time period (covering both the pre- and post-construction periods), while gender, race and education indicators are only available starting in 2009.

7.1.3.1 Income

Low-income employment increased on the treatment corridor during the year of the bike lane construction, but high-income employment increased in subsequent years and remained at a relatively high level compared to the years before the street improvement. On the control corridor, the income-level composition stayed constant across the years of analysis, except for a slight increase after 2014. However, as we mentioned before, the income brackets of the LEHD data are not indexed by inflation, so the increase in the percentage of high-income employment may be purely an inflationary effect.

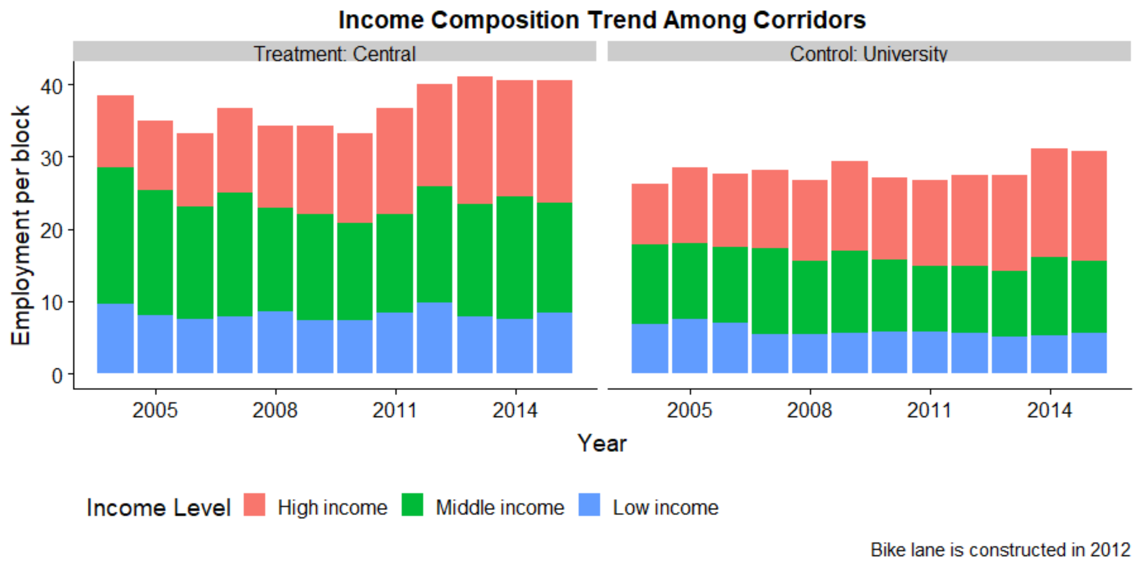


Figure 7-11. Central Avenue Income Employment Level Composition Trend

7.1.3.2 Race

7.1.3.2.1 Employment:

In terms of employment racial composition, we observed a decrease in the percentage of white employment along the Central Avenue corridor, combined with a corresponding increase in the percentage of black employment during this same time period. The treatment corridor also experienced a decrease in Asian employment. White employment was still the dominant employment racial group in both corridors. Generally, the employment racial composition trend on the treatment corridor followed a similar trend as the control corridor and the city as a whole.

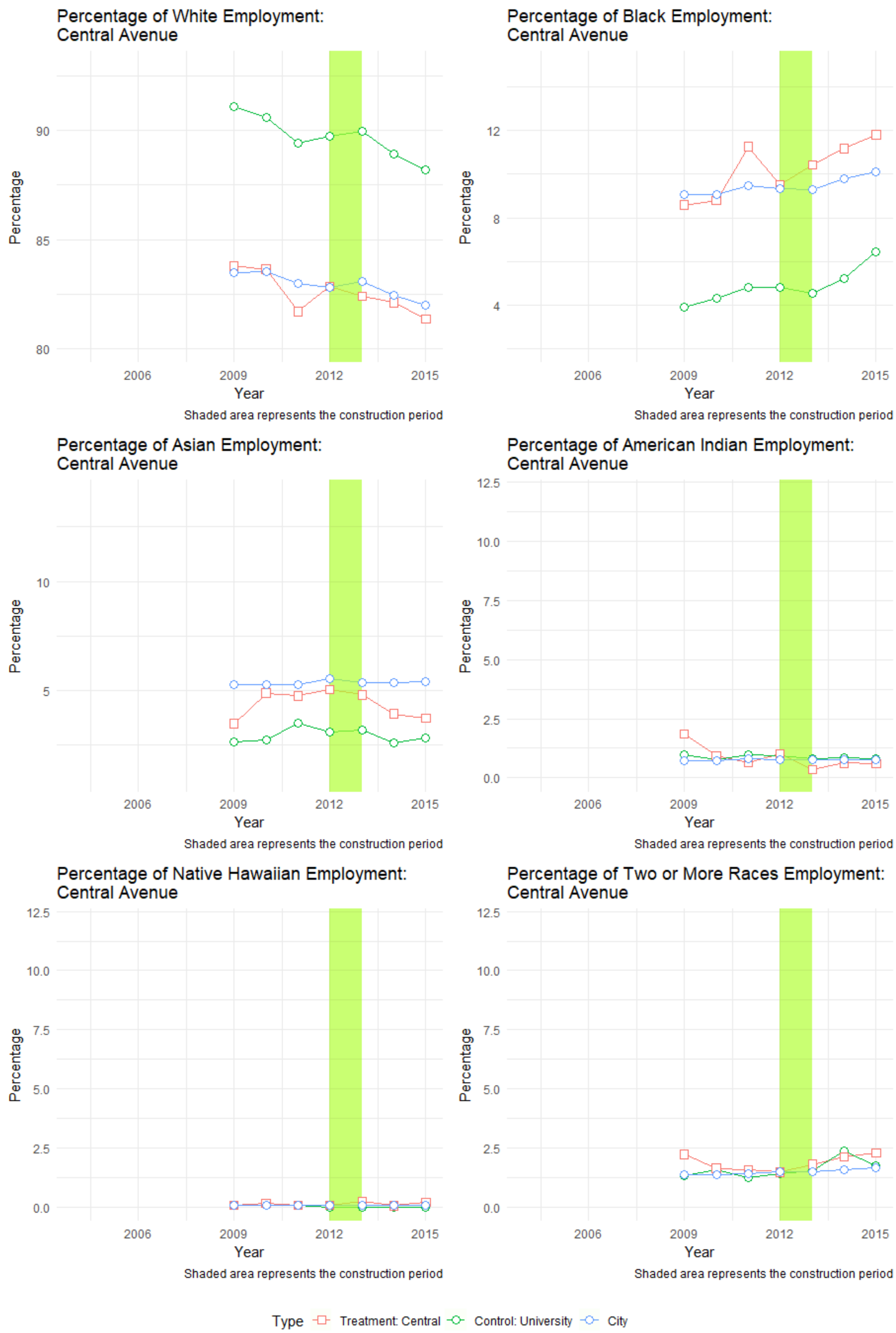


Figure 7-12. Central Avenue Employment Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

This table below shows similar results as the above graphs, that the employment racial composition trend of Central Avenue treatment corridor is similar to the overall city trend, but with greater percentage changes. Due to the fuzzy factor applied in the LEHD data, there are some unexpected fluctuations in the annual trend. Table 7-17 below summarizes the average percentage change of the racial composition of residents along the treatment and control corridors between 2012 and 2015. While some percentage changes appear large, the actual change may be still small due to the small number of these racial groups in the starting year.

Table 7-17. Central Avenue Employment Racial Composition Percentage Change (in percentage)

	Treatment: Central	**Control: University**	**City**
White	-0.44	-0.43	-0.24
Black	5.39	8.41	2.06
American Indian	-10.14	-2.94	0.05
Asian	-6.47	-2.25	-0.54
Hawaiian	48.17	NA	5.36
Two or more races	13.97	5.56	2.59

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

7.1.3.2.2 Residents

The racial composition graphs of the residents in the corridors indicate a slightly different trend than the employment racial composition trends. The percentage of white and Asian residents decreased slightly on the treatment corridor, while other races all increased. On the control corridor, the percentage of black residents increased slightly, while other races all decreased. However, there were generally very small fluctuations in all resident races over the years. We conclude that this preliminary analysis did not provide evidence of significant changes in the resident racial composition on Central Avenue that differs from the control corridor or the city.

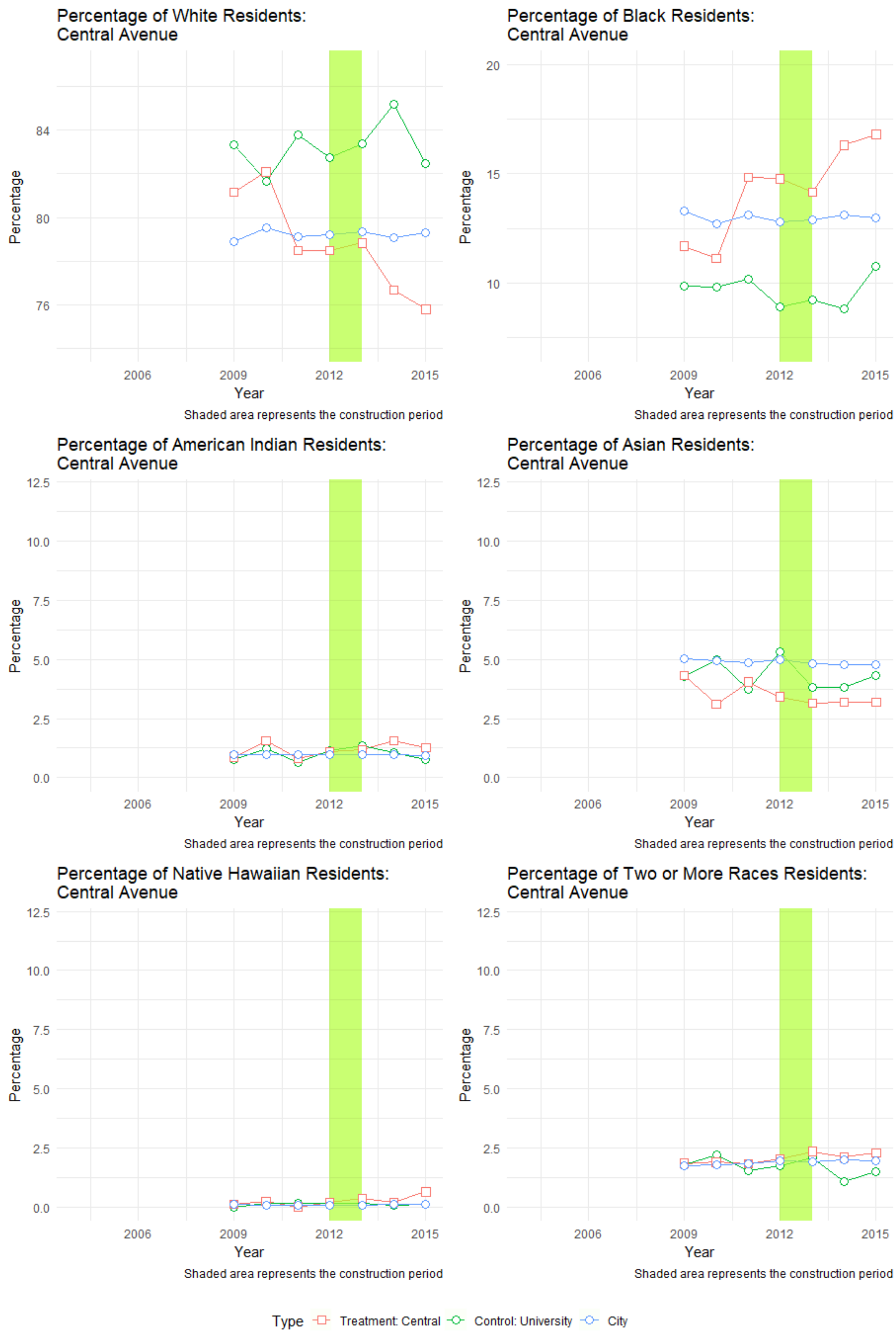


Figure 7-13. Central Avenue Residents Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

The table below shows similar results as the above graphs, with the percentage of white and Asian residents decreasing slightly and the percentage of other races increasing slightly on the treatment corridor. On the University Avenue control corridor, the percentage of black residents increased in recent years, while other races all decreased slightly. However, as we discussed, there were generally small changes in the number of residents in each race, and these fluctuations might not be the actual change due to the fuzzy techniques employed on the LEHD data.

Table 7-18. Central Avenue Residents Racial Composition Percentage Change (in percentage)

	Treatment: Central	**Control: University**	**City**
White	-0.85	-0.08	0.02
Black	3.34	5.30	0.30
American Indian	3.84	-7.90	-0.78
Asian	-1.61	-4.63	-1.01
Hawaiian	61.54	-2.65	4.44
Two or more races	3.10	-3.51	0.04

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

7.1.3.3 Education

7.1.3.3.1 Employment

In terms of education attainment, the selected corridors had less higher-educated employment, but more high school and below employment. The Central Avenue corridor generally had a similar trend as the control corridor, with the exception that the percentage of bachelor’s or above employment increased slightly after the bike lane installation.

The percentage change table (Table 7-19) shows a similar trend as the graph. The treatment corridor experienced generally similar employment educational attainment change as the city and control corridor. We observe a slight increase in higher-educated employment, which might be an indication of an industrial shift to industries that require more skilled or educated labor in this area.

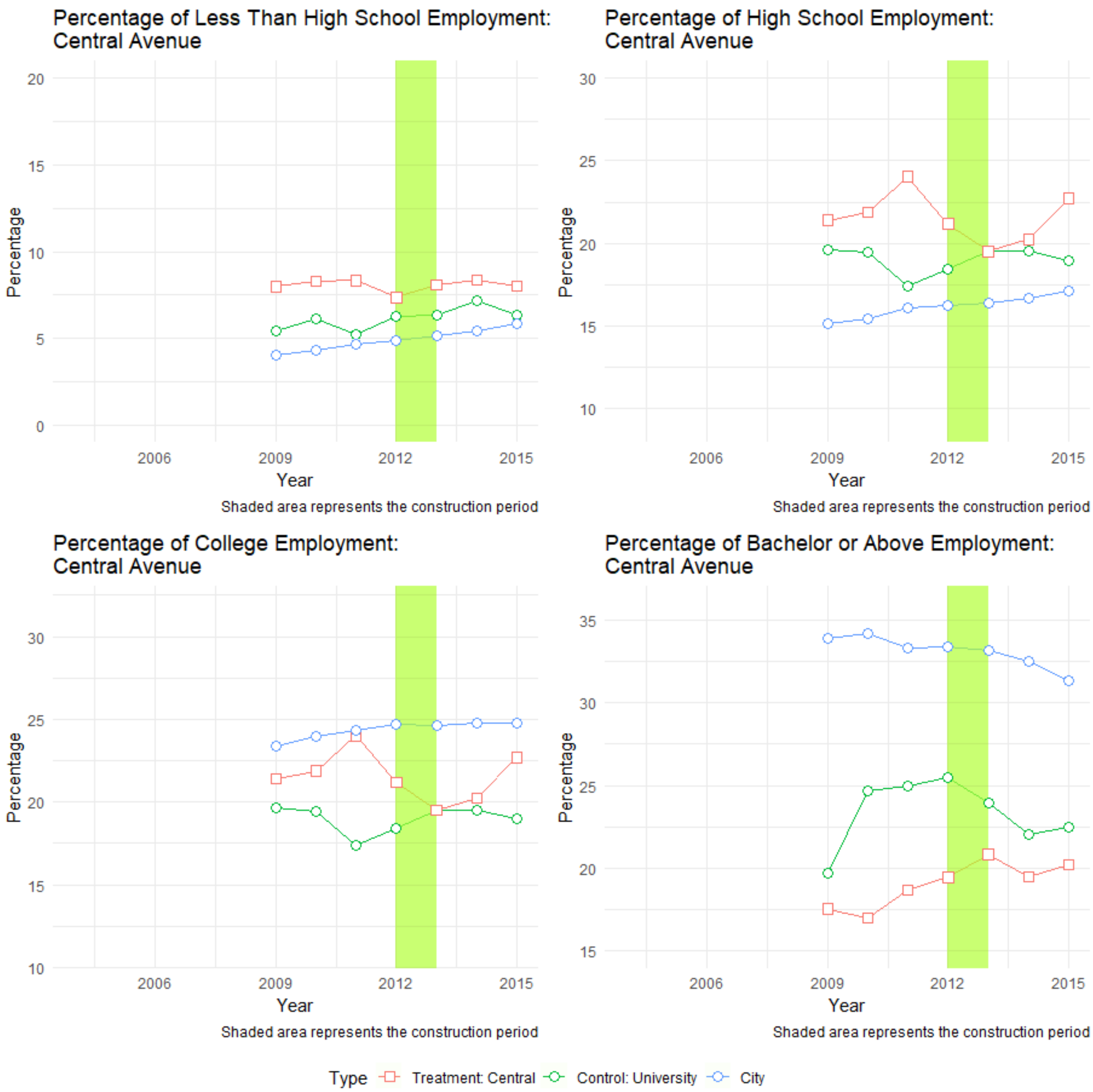


Figure 7-14. Central Avenue Employment Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 7-19. Central Avenue Employment Education Level Composition Percentage Change (in percentage)

	Treatment: Central	Control: University	City
Less than high school	2.20	0.38	5.04
High school	1.80	0.74	1.34
College	1.80	0.74	0.07
Bachelor’s or above	1.00	-2.91	-1.53

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

7.1.3.3.2 Residents

In terms of residents’ education level, the trend graphs show a more volatile pattern than the graphs of employment education level. On the treatment corridor, high school-level residents increased and college-level residents decreased, while the other two categories stayed constant between the construction years of 2012 and 2015. Resident education attainment trends along the control corridor generally track the pattern on the treatment corridor, although the increases and decreases are of greater magnitude. Similar to the employment education composition trend, we again observed a slight increase in the percentage of bachelor’s-level residents on the treatment corridor, but see decreases of the same on the control corridor and in the city overall.

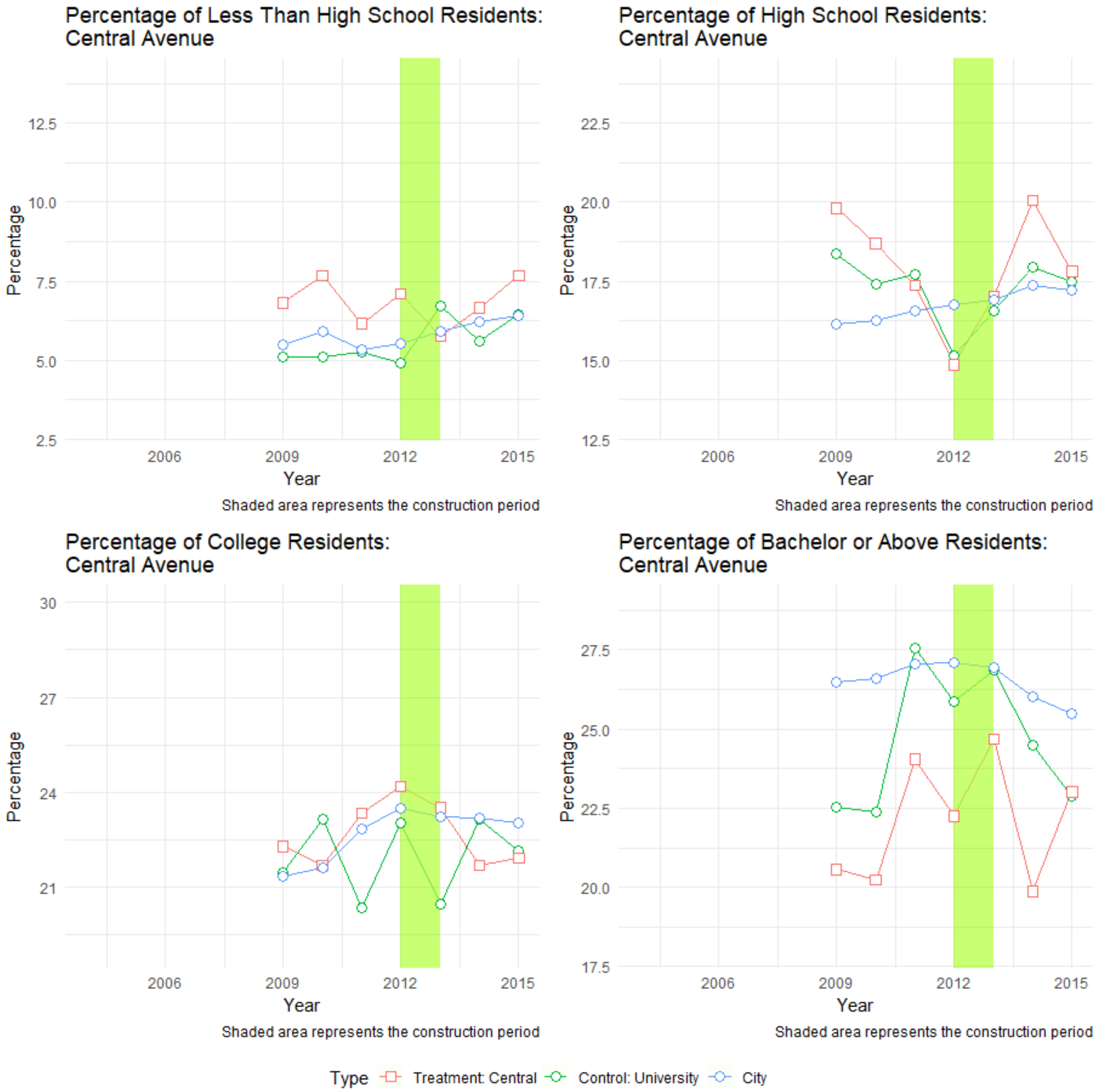


Figure 7-15. Central Avenue Residents Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 7-20. Central Avenue Residents Education Level Composition Percentage Change (in percentage)

	Treatment: Central	Control: University	City
Less than high school	1.97	7.75	4.03
High school	4.94	3.60	0.69
College	-2.35	-0.95	-0.47
Bachelor's or above	0.85	-2.88	-1.48

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

7.1.3.4 Gender

In terms of gender composition, the treatment corridor experienced sharp increases in female employment, while the control corridor showed slight decreases. However, there was much less female employment on the treatment corridor to begin with, which may contribute to the larger percentage increases. There was relatively less change in the female resident percentage during the years of analysis.

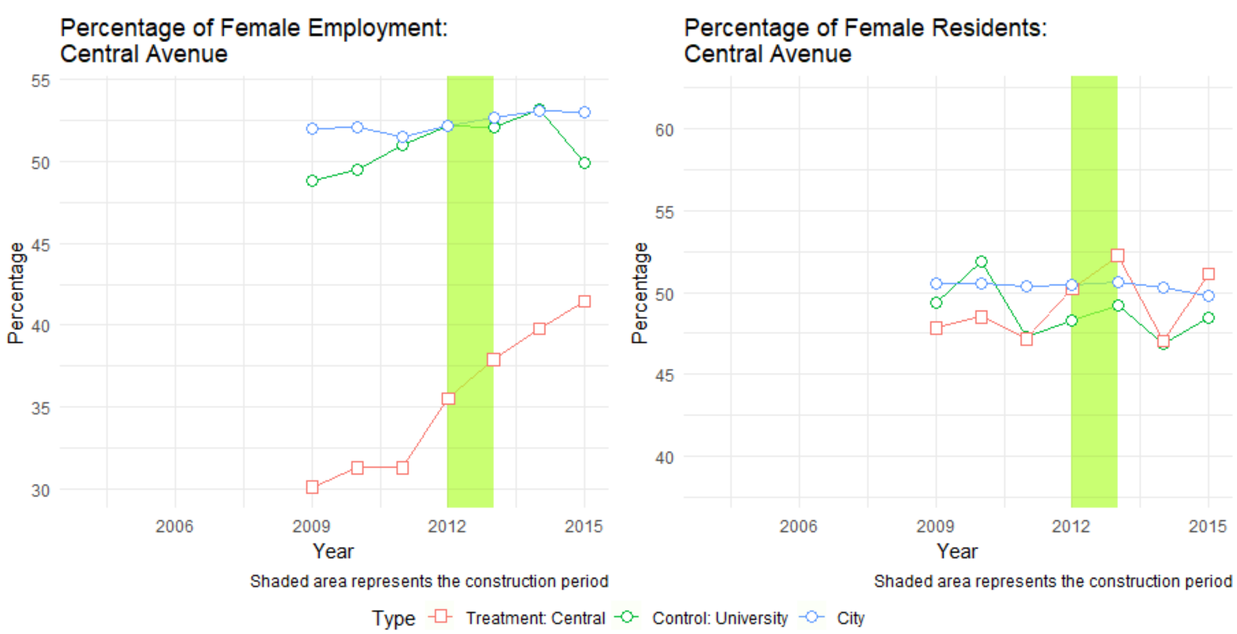


Figure 7-16. Central Avenue Gender Composition Trend

In general, we do not observe any divergent pattern in the demographic changes along the street improvement corridor when compared with the control corridor or the city. Although there were trends of increasing female employment and higher-educated population on the treatment corridor, the changes were not substantial.

7.1.4 Central Avenue Corridor Summary

We used four different data sources, LEHD employment data, retail sales tax data, QCEW data and NETS employment and sales revenue data, to analyze the economic and equity impacts of street improvement on the Central Avenue corridor. Each of these data sources was analyzed using the aggregated trend analysis, DID estimation and ITS estimation approaches, and we were able to conclude that:

- Retail and food service employment on Central Avenue increased after the bike lane construction. Both the trend analysis and the DID models show evidence that the growth in employment on Central Avenue is on par with the control corridor. In addition, the ITS approach shows a positive growth trend impact of the bike lane construction using LEHD data and QCEW wages data.
- In terms of sales data, the aggregated trend analysis approach shows that retail sales in the treatment corridor increased faster than the control corridor. However, additional econometric analyses suggest the impact is not statistically significant.
- There is a very apparent trend that restaurant sales on Central Avenue increased dramatically following the bike lane installation. Both trend analysis and the ITS approach confirm the positive impact of the bike lane installation on restaurant sales on Central Avenue.
- There were some disparities of included industries or geographical scales in the data collection process, contributing to different results. For example, the industry sector of LHED data is only available to a two-digit NAICS code while QCEW data and NETS data can go down to more digits, which allows us to exclude the unnecessary industry sectors (i.e., gas stations) from the impact of the street improvement. This emphasizes the importance of using multiple data sources to validate the accuracy of economic trends in the future.
- In general, ITS analysis provides more robust results than the other two methods, since it will less likely be affected by the selection of control corridors. In particular, if the two corridors had very different economic indicator levels, the DID analysis would lead to (confirmed by both trend analysis and the ITS approach) the opposite result as the aggregated trend shown in the case of the restaurant sales case on Central Avenue.

- In terms of distributional analysis, we do not observe any significant divergent patterns in the environmental justice indicators along the street improvement corridor when compared with the control corridor or the city.

7.2 FRANKLIN AVENUE

Franklin Avenue's bike lane was installed in 2011 and involved the removal of a parking lane. The control corridor is designated as another segment of Franklin Avenue where the street improvement project was not constructed.

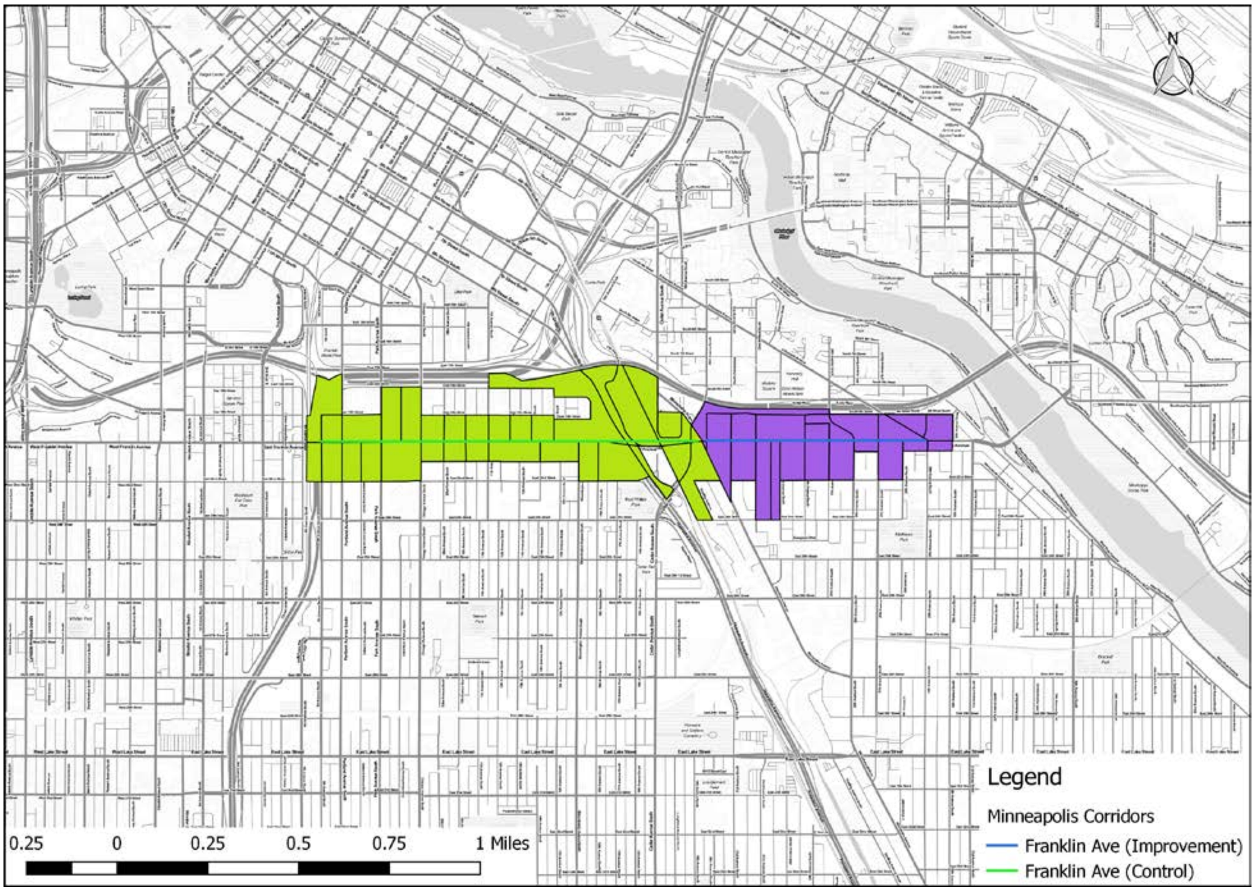


Figure 7-17. Minneapolis Franklin Avenue Corridors

7.2.1 Corridor Selection

Both sections of Franklin Avenue are vital business corridors. As of 2010, the average business-related (retail and food and accommodation service) employment per block were 16 and 6 for the treatment and comparison corridors, respectively. The two corridors had similar food and accommodation employment, but the treatment corridor had much more retail employment than the control corridor, as shown in the comparison table below (Table 7-21).

Table 7-21. Comparison of Business Jobs Per Block Percentiles Among Franklin Corridors

Corridor	Tot Emp	Retail Emp	Food Emp	Tot (%)	Retail (%)	Food (%)
Franklin (improvement)	60	8	8	60-65	70-75	60-65
Franklin (control)	104	1	5	70-75	45-50	55-50

In addition, we compared business jobs as a percentage of all other service jobs for each block. On the treatment corridor, 54% of all service jobs were business jobs and the number for the comparison corridor was 43%, which was not statistically different according to the t-test result. We further compared the average business job annual growth rates before the improvement completion, 2002-2011, for the two corridors. The annual growth rate on the treatment corridor was 0.5% compared to 8.1% for the comparison corridor, but there were no statistically significant differences at the 95% confidence interval between the two corridors. In terms of street characteristics, they are both local streets located along the same corridor south of downtown Minneapolis. In sum, while there are some differences between the two Franklin Avenue corridors, they are sufficiently comparable with each other for this analysis.

Table 7-22. Study and Comparison Corridor Selection Criteria (Franklin Corridor)

<table>
<tr><td>Treatment Corridor</td><td rowspan="2" colspan="2">Indicator</td><td>Central</td></tr>
<tr><td>Control Corridor</td><td>University</td></tr>
<tr><td rowspan="3">Transportation/ Geography</td><td colspan="2">Geographic Proximity</td><td>□</td></tr>
<tr><td colspan="2">Street Classification</td><td>□</td></tr>
<tr><td colspan="2">Role in Street Network</td><td>□</td></tr>
<tr><td rowspan="5">Business Activity</td><td rowspan="2">Job Density Percentile</td><td>Retail</td><td>□</td></tr>
<tr><td>Food</td><td>□</td></tr>
<tr><td colspan="2">Share of Business Jobs</td><td>□</td></tr>
<tr><td rowspan="2">Employment Growth Rate</td><td>Retail</td><td>□</td></tr>
<tr><td>Food</td><td>□</td></tr>
</table>

7.2.2 Economic Outcome Analysis

7.2.2.1 LEHD Data

7.2.2.1.1 Aggregated Trend Analysis

Retail employment increased greatly right after street improvement, and maintained consistent, though moderate, growth on the Franklin Avenue improvement corridor. While the Franklin Avenue control corridor lagged in retail employment growth during this same period, it did experience a dramatic spike starting in 2014 but is unlikely related to the street improvement event. However, we observe that Franklin Avenue, on both the treatment and control corridors, had greater growth in retail employment than the city as a whole.

In terms of food employment, the aggregated trend analysis is relatively ambiguous. In the post-construction period after 2011, both the improvement and control corridor food employment remained flat to slightly negative. This situation did not change until the dramatic spike that occurred on the improved portion of Franklin Avenue, but given the timing, it is also unlikely the construction itself was responsible for this dramatic change.

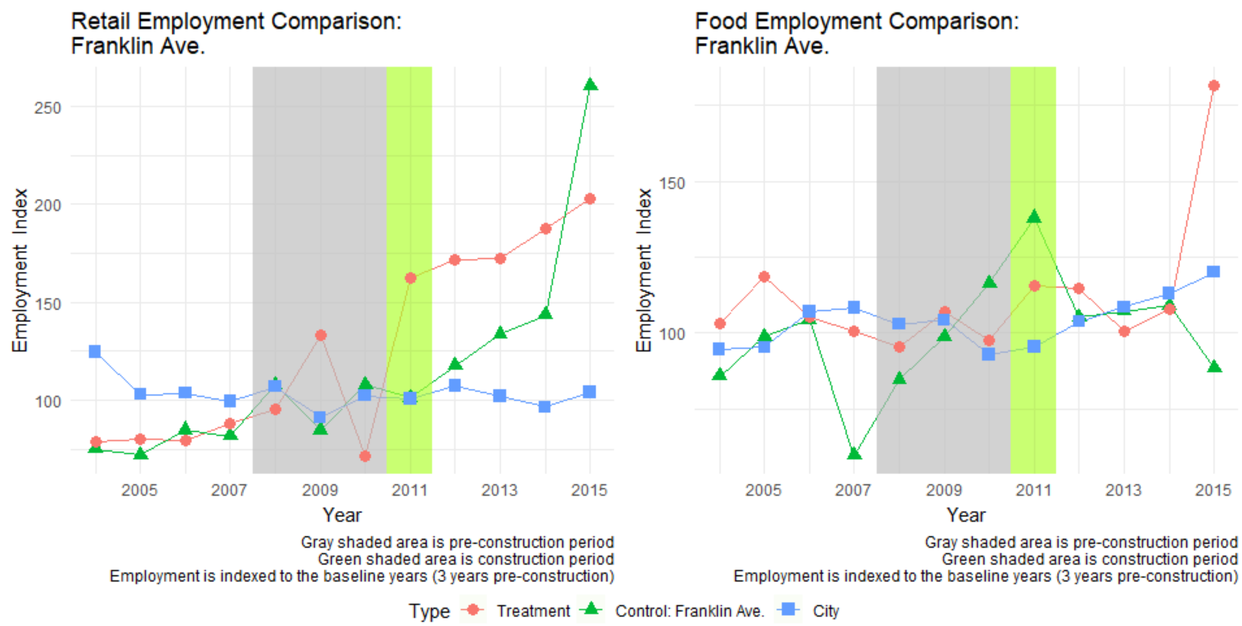


Figure 7-18. Aggregated Employment Trend of Franklin Corridor and Control Corridors (LEHD Data)

Table 7-23. Franklin Corridor Trend Analysis Summary Table (LEHD Data)

Area	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
LEHD: [employment]												
Treatment	169	-3.24%	71.60%	0.34%	8.93%	26.96%	130	1.73%	14.62%	-12.08%	6.87%	3.14%
Control: Franklin	31	2.86%	16.13%	13.89%	7.32%	12.44%	107	17.20%	5.61%	1.77%	1.74%	3.04%

[1] Baseline is defined as the average of previous three years before construction year;
[2] Pre-growth rate is defined as average of baseline annual growth rate;
[3] 1st year growth rate is defined as the growth rate of the year after construction compared to baseline.

7.2.2.1.2 Difference-in-Difference (DID) Analysis

The DID analysis of LEHD data indicates there was a positive impact of the bike lane installation on the improved Franklin Avenue corridor for retail employment. However, the same effect does not extend to food and accommodation employment.

Figure 7-19. Franklin Avenue Corridor DID Regression Results (LEHD Data)

	Dependent variable:		
	Retail Emp.	Accommodations Emp.	'Business' Emp.
Type: treatment	139.250^{***}	31.500^{**}	170.750^{***}
	(17.327)	(12.501)	(23.910)
Pre/post	22.875	4.500	27.375
	(21.221)	(15.311)	(29.283)
DID estimator: treatment	120.750^{***}	22.500	143.250^{***}
	(30.011)	(21.652)	(41.413)
Constant	27.375^{**}	105.500^{***}	132.875^{***}
	(12.252)	(8.840)	(16.907)
Observations	24	24	24
R^2	0.912	0.471	0.889
Adjusted R^2	0.899	0.391	0.872
Residual Std. Error (df = 20)	34.653	25.002	47.820
F Statistic (df = 3; 20)	69.318^{***}	5.932^{***}	53.364^{***}
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$		

7.2.2.1.3 Interrupted Time Series (ITS) Analysis

We found some mixed results when conducting ITS analyses on the Franklin Avenue treatment and control corridors. The street improvement corridor lost a significant number of food service jobs, indicated by the large negative and statistically significant change in the level coefficient, but also a positive shift in the slope. This is seen visually in the aggregate employment chart (Figure 7-18) for food employment on the improved Franklin Avenue corridor where there is a clear drop in employment after the construction (negative change in level) and then sizable growth in employment between 2014 and 2015 (positive shift in slope). Due to a lack of further data points beyond 2015, it is unclear whether this rise will taper off, creating a new, higher level of employment, but it does seem likely that the corridor potentially has a positive shift in food employment.

Table 7-24. Franklin Avenue Corridor ITS Regression Results (LEHD Data)

	Dependent variable:		
	Retail Emp.	Accommodations Emp.	'Business' Emp.
Yearly trend	14.393**	-0.286	14.107
	(6.040)	(3.536)	(8.005)
Level change	14.143	-257.786**	-243.643
	(187.355)	(109.685)	(248.285)
Slope change	4.107	27.286**	31.393
	(18.519)	(10.842)	(24.542)
Constant	101.857**	138.286***	240.143***
	(30.502)	(17.857)	(40.421)
Observations	12	12	12
R^2	0.842	0.571	0.817
Adjusted R^2	0.783	0.410	0.749
Residual Std. Error (df = 8)	39.145	22.917	51.876
F Statistic (df = 3; 8)	14.231***	3.549*	11.934***
Note:	*p<0.1; **p<0.05; ***p<0.01		

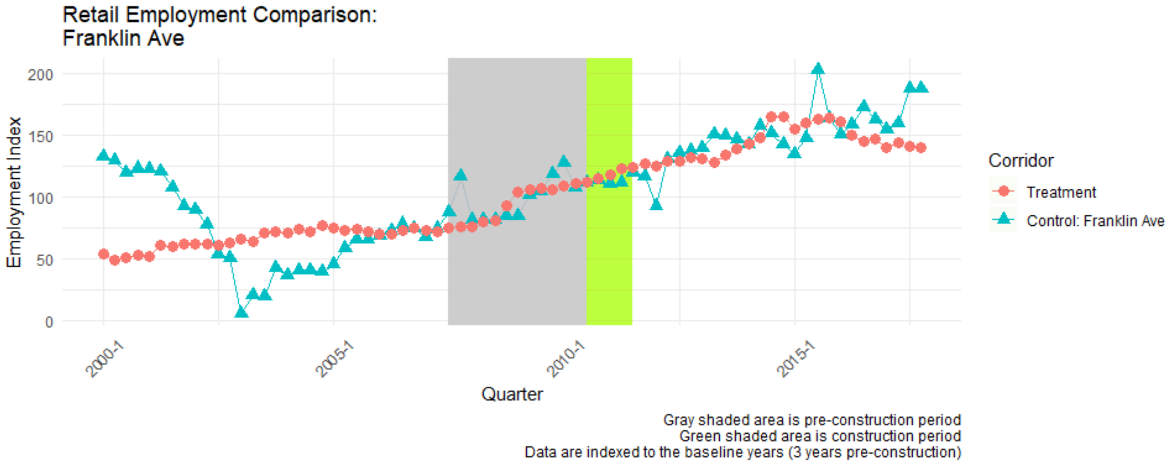
7.2.2.2 QCEW Data

7.2.2.2.1 Aggregated Trend Analysis

Analysis of the more accurate and detailed QCEW data indicates that the treated section of the Franklin Avenue corridor has significantly more retail employment and retail wages than the control area, but note the accelerated change in slope on the treated section a little before 2010 that carries through the construction period and finally moderates and drops in the last few quarters. This is in comparison to the relatively flat overall growth of the control section.

Figure 7-20. Aggregated Retail Sales Trend of Central Corridor and Control Corridors (Retail Sales Tax Data)

The following indexed figures for both total wages and average employment growth show the two corridors tracking each other closely in terms of growth rates, with a slight divergence in later quarters on the treated section of the corridor. This follows logically given the fact that these are two sections of the same stretch of street. That being said, the corridor has seen robust, consistent growth over time, though it is not immediately apparent if the infrastructure construction had a clear effect from the aggregated trend analysis alone.



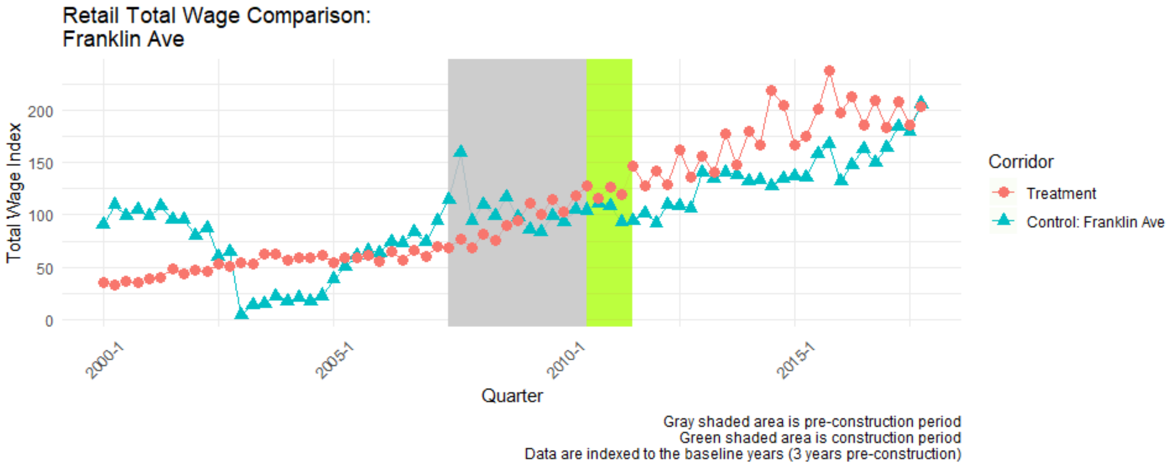


Figure 7-21. Indexed Aggregated Retail Sales Trend of Central Corridor and Control Corridors (Retail Sales Tax Data)

Table 7-25. Franklin Corridor Trend Analysis Summary Table (QCEW Data)

	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
Area	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
QCEW: [employment]												
Treatment	214	16.90 %	28.89 %	3.23%	16.68%	16.27 %	-	-	-	-	-	-
Control: Franklin	44	18.32 %	23.67 %	18.07%	1.30%	14.45 %	-	-	-	-	-	-

[1] Baseline is defined as the average of previous three years before construction year;
[2] Pre-growth rate is defined as average of baseline annual growth rate;
[3] 1st year growth rate is defined as the growth rate of the year after construction compared to baseline.

7.2.2.2.2 Interrupted Time Series (ITS) Analysis

The QCEW ITS models largely do not find an effect of construction except for the slope change term for total wages. In the case of total wages, the ITS estimate is positive and significant. But considering that the employment model is non-significant across all terms and the level change term is negative and non-significant for wages, this does not support a causal relationship between the new cycling infrastructure and retail employment or wages.

Table 7-26. Franklin Avenue Corridor ITS Regression Results (Retail Sales Tax Data)

	Dependent variable:	
	Average Employment	Total Wages
Yearly trend	10.893^{***}	$343{,}091.200^{***}$
	(1.860)	(51,114.950)
Level change	61.063	-1,728,766.000
	(53.283)	(1,464,347.000)
Slope change	-1.307	$278{,}530.000^{**}$
	(4.129)	(113,477.200)
Constant	108.110^{***}	$1{,}560{,}070.000^{***}$
	(11.003)	(302,400.100)
Observations	18	18
R^2	0.950	0.972
Adjusted R^2	0.939	0.967
Residual Std. Error (df = 14)	19.507	536,098.100
F Statistic (df = 3; 14)	87.982^{***}	164.758^{***}
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

7.2.2.3 NETS Data

7.2.2.3.1 Aggregated Trend Analysis

The following tables and figures present the employment and sales change before and after the street improvement on the two Franklin Avenue corridors using the NETS dataset. As described previously in the data section, economic data from two types of industry categories are presented here: Type I includes all retail and food service establishments on the abutting blocks of the corridor, and Type II includes a refined subset of establishments directly facing the corridor (block-face establishments). Since the treatment and control corridors in this particular scenario are neighboring streets parallel to each other, Type I block-level data on the two corridors may include overlapping establishments.

In terms of the Type I industry (directly corresponding to LEHD industry categories), the treatment corridor experienced fluctuations in retail employment and sales, and declined after two years of the street improvement. The retail-sector trends generally followed the city as a whole, but performed worse than the control corridor. On the other hand, the economic performance of the food service industry on the treatment Franklin Avenue corridor was similar to the control corridor, but was worse than the city as a whole.

Table 7-27. Franklin Corridor Aggregated Employment Changes Post-Improvement (NETS Data, industry type I)

Corridor	Baseline employment (2011)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Franklin	191	143	0.53%	0%	-4.19%	2.10%	1.64%	-13.70%
Franklin (control)	73	294	13.70%	0.68%	0%	-6.75%	8.43%	0%
Minneapolis	67,181	41,229	-0.24%	0.08%	-1.33%	1.84%	-3.35%	0.11%

Table 7-28. Franklin Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, industry type I)

Corridor	Baseline sales (2011)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Franklin	17,134,215	4,557,700	0.62%	0.18%	-0.71%	3.26%	4.58%	-13.13%
Franklin (control)	6,155,400	9,470,700	8.97%	1.76%	1.62%	-7.46%	10.41%	2.12%
Minneapolis	9,723,984,496	1,334,028,984	1.34%	0.57%	-3.42%	2.94%	-1.41%	0.94%

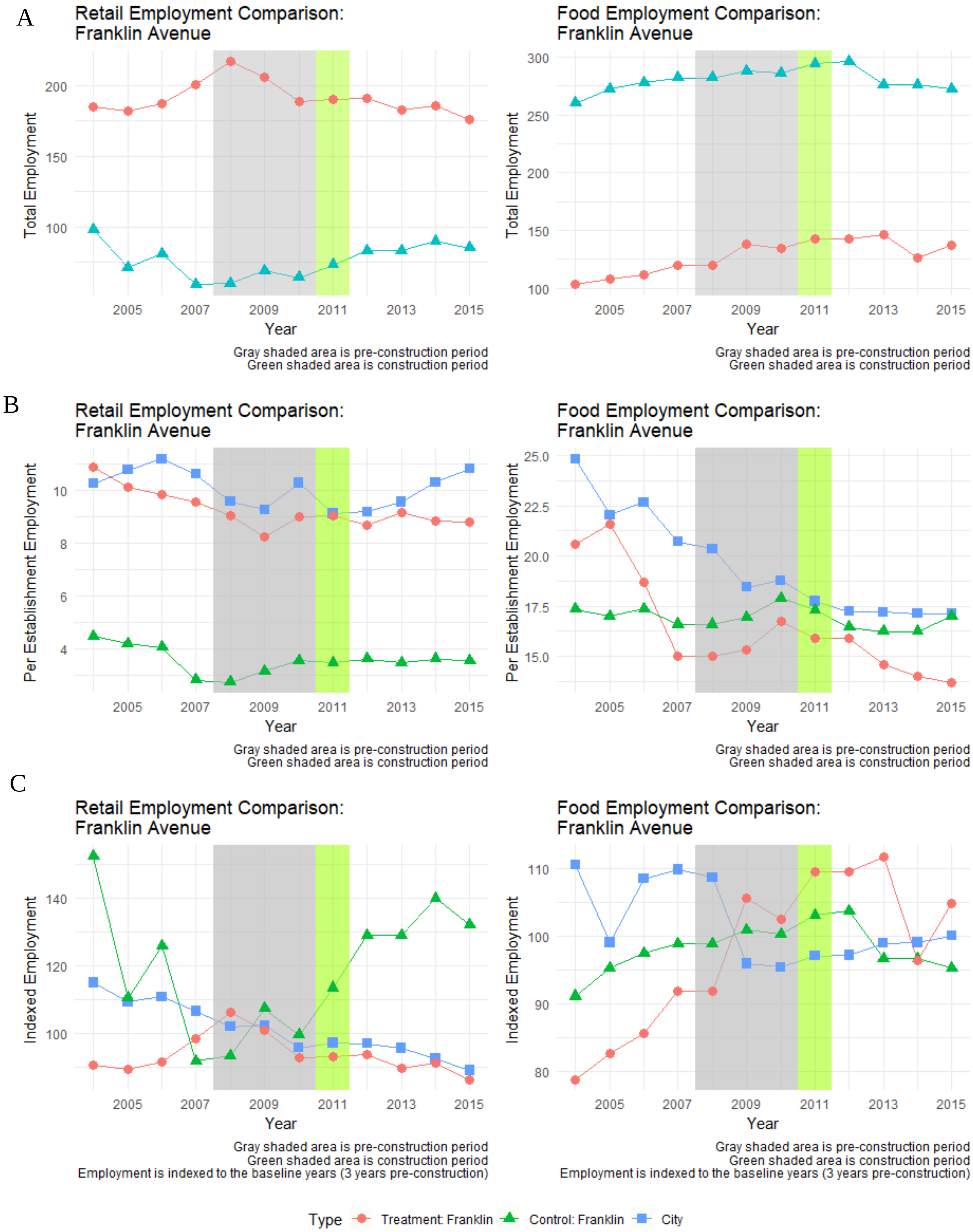


Figure 7-22. Aggregated Employment Trend of Franklin Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type I

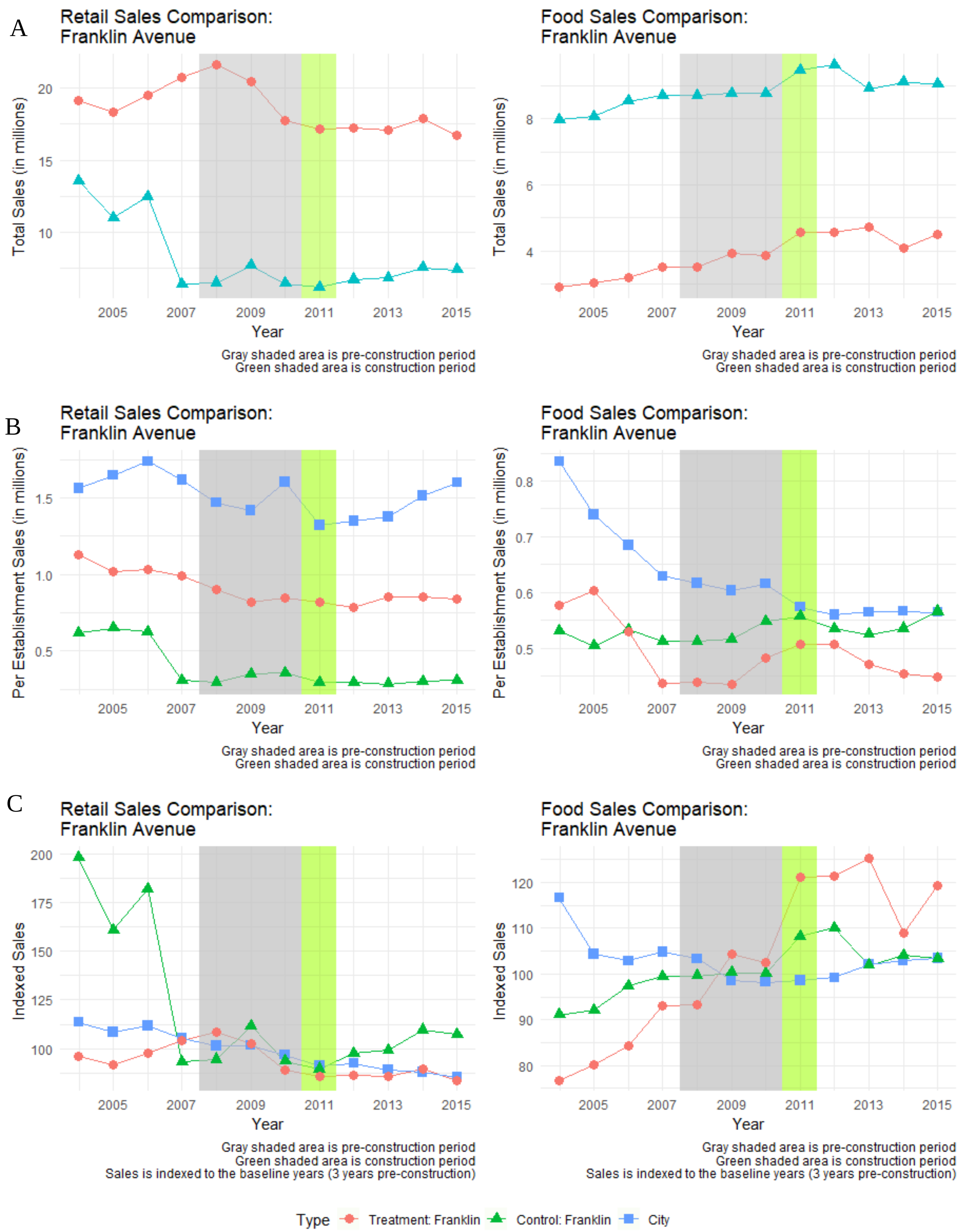


Figure 7-23. Aggregated Sales Trend of Franklin Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type I

The more refined Type II industry block-face-level establishments generally followed a similar trend as the Type I employment and sales trends. Retail employment and sales on the treatment portion of Franklin Avenue decreased after the construction year, while the control corridor increased significantly. The treatment corridor experienced some increases in food service employment right after the bike lane installation, but both employment and sales started to experience some declines in the third year. However, the improved Franklin Avenue corridor performed better economically than the corresponding unimproved Franklin Avenue corridor.

Table 7-29. Franklin Corridor Aggregated Employment Changes Post-Improvement (NETS Data, Industry Type II)

Corridor	Baseline employment (2011)		Employment change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Franklin	191	143	1.31%	0%	-4.54%	3.19%	1.31%	-20.61%
Franklin (control)	52	127	23.08%	0%	0%	-15.75%	10.93%	0%
Minneapolis	39,641	49,740	0.85%	-0.10%	-1.76%	1.46%	-3.92%	-0.04%

Table 7-30. Franklin Corridor Aggregated Retail Sales Changes Post-Improvement (NETS Data, Industry Type II)

Corridor	Baseline sales (2011)		Sales tax change post-improvement					
			1st year		2nd year		3rd year	
	Retail	Food	Retail	Food	Retail	Food	Retail	Food
Franklin	13,207,115	3,042,700	1.15%	0.28%	-1.99%	4.72%	3.08%	-18.46%
Franklin (control)	4,706,300	4,226,300	14.56%	-0.07%	1.53%	-15.89%	12.51%	1.63%
Minneapolis	5,906,874,901	1,280,493,884	5.15%	0.22%	-1.49%	2.63%	-2.40%	0.47%

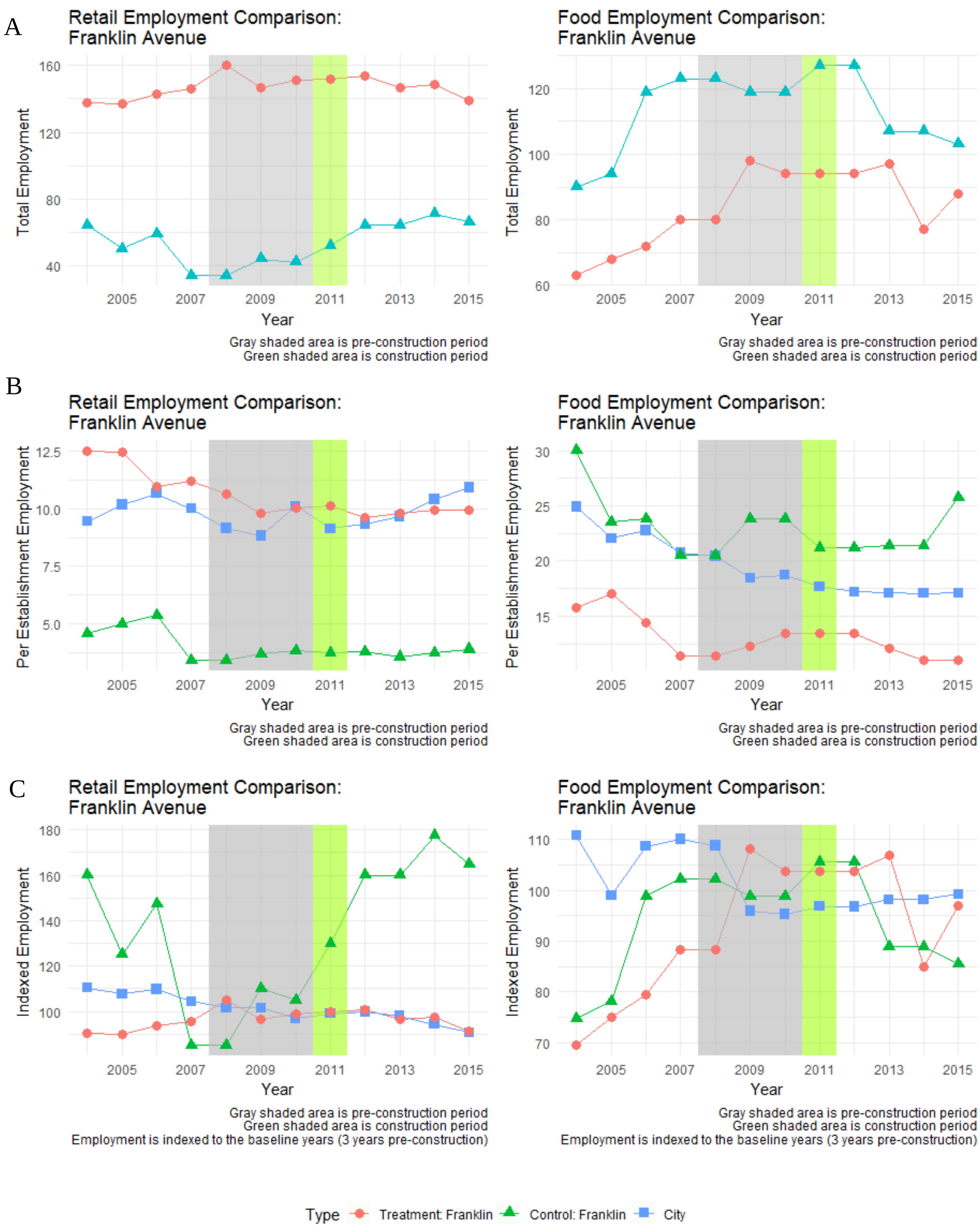


Figure 7-24. Aggregated Employment Trend of Franklin Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type II

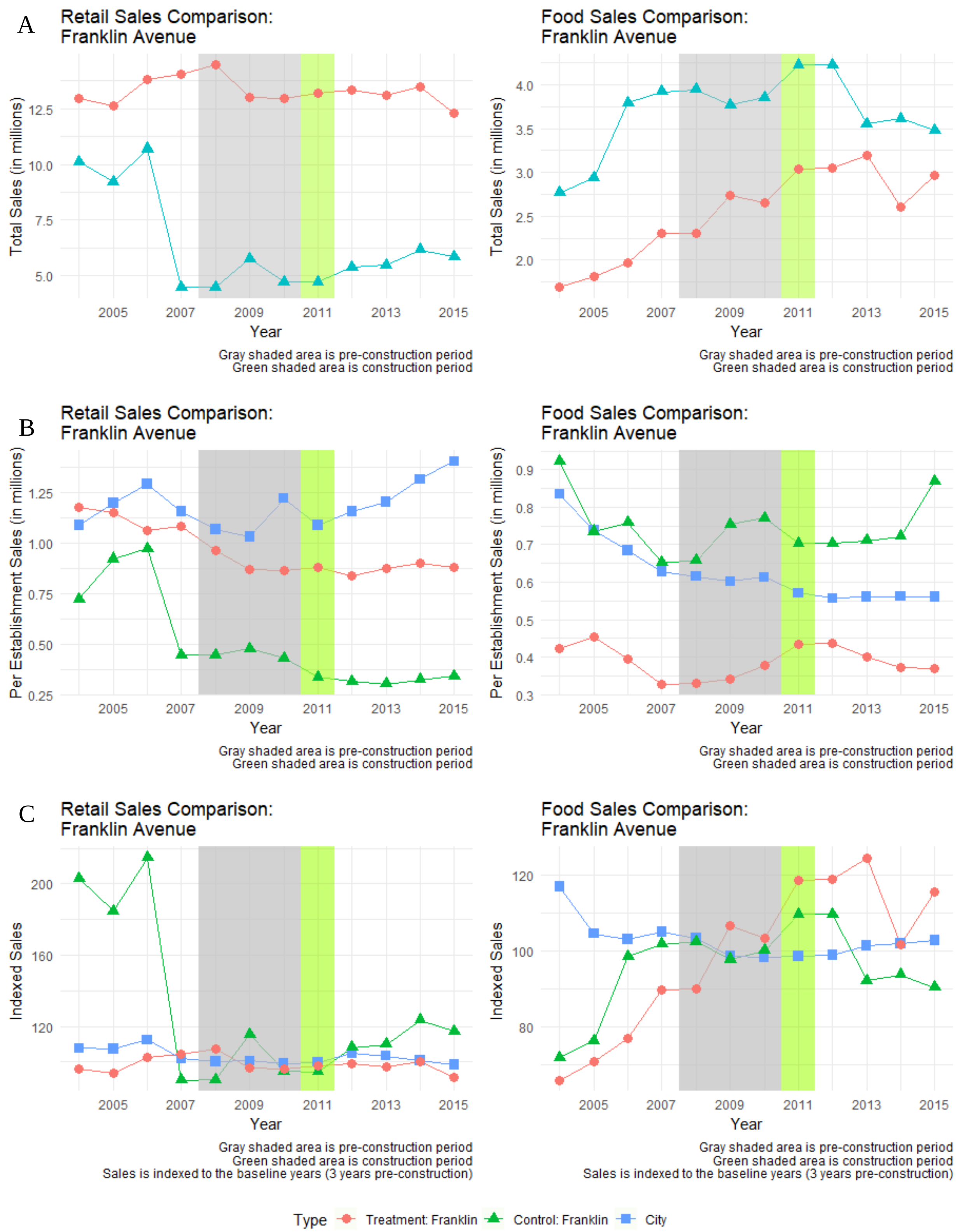


Figure 7-25. Aggregated Sales Trend of Franklin Corridor and Control Corridors by NETS Data (A: Total Employment; B: Employment per Establishment; C: Indexed Employment) – Industry Type II

7.2.2.3.2 *Difference-in-Difference (DID) Analysis*

DID estimations of the NETS dataset are presented below. Since the NETS dataset has longer historical data, we chose to use the data between 2005 and 2015 for our analysis to maintain consistency, and limit this analysis to only the Type II establishments as these are the businesses that directly face the street improvement corridor. The results indicate that the control corridor had significant positive DID estimator in retail service employment, and a negative DID estimator in food service employment and sales. This means that the treatment corridor had 25 less retail jobs, 17 more food service jobs, and $754,181 more in food sales on average than the control corridor after the installation of the street improvement. We further investigate the different impacts on retail and food service employment by combining the retail and food service employment together as business employment. The model results show there was no significant impact of the street improvement on business employment. Therefore, we may be able to infer that the opposing impacts on retail and food service employment from the street improvement might be due to an industrial shift from retail to more food service on the treatment corridor.

Table 7-31. Franklin Corridor DID Regression Results (NETS Data)

	Dependent variable:					
		Employment			Sales	
	Retail	Food	Business	Retail	Food	Business
TypeControl	-103.429***	35.000***	-68.429***	-7,803,876.000***	1,380,214.000***	-6,423,661.000***
	(4.444)	(3.961)	(6.324)	(766,685.400)	(157,433.600)	(733,830.400)
prepost	-5.429	-0.095	-5.524	-581,890.300	339,866.700	-242,023.700
	(5.737)	(5.114)	(8.165)	(989,786.600)	(203,245.900)	(947,371.000)
TypeControl: DID estimator	25.429***	-16.667**	8.762	662,209.400	-754,181.000**	-91,971.570
	(8.113)	(7.232)	(11.547)	(1,399,770.000)	(287,433.100)	(1,339,785.000)
Constant	150.429***	87.429***	237.857***	13,549,990.000***	2,581,300.000***	16,131,290.000***
	(3.142)	(2.801)	(4.472)	(542,128.500)	(111,322.400)	(518,896.500)
Observations	20	20	20	20	20	20
R^2	0.977	0.853	0.907	0.898	0.840	0.874
Adjusted R^2	0.973	0.825	0.889	0.879	0.809	0.850
Residual Std. Error (df = 16)	8.313	7.411	11.832	1,434,337.000	294,531.300	1,372,871.000
F Statistic (df = 3; 16)	225.689***	30.892***	51.751***	46.974***	27.901***	36.866***
Note:	**p<0.1; ****p<0.05;** ***p<0.01					

7.2.2.3.3 *Interrupted Time Series (ITS) Analysis*

Similar to DID analysis, we only conducted the ITS analysis on Type II block-face-level establishments using NETS data, and chose to utilize only the data between 2005 and 2015 for this analysis. The models indicate that the street improvement had a significant positive coefficient for business employment, which meant the level of business employment dropped by 119 right after the street improvement, but the growth rate increased significantly.

Table 7-32. Franklin Corridor ITS Regression Results (NETS Data)

	Dependent variable:					
	Employment			Sales		
	Retail	Food	Business	Retail	Food	Business
Yearly trend	1.286	3.857**	5.143***	-161,540.200	180,667.900***	19,127.680
	(1.010)	(1.409)	(1.240)	(98,566.300)	(36,270.310)	(82,734.240)
Level change	46.286	72.548	118.833*	2,735,662.000	2,704,274.000	5,439,936.000
	(42.177)	(58.811)	(51.788)	(4,115,463.000)	(1,514,403.000)	(3,454,423.000)
Slope change	-5.286	-8.357	-13.643**	-228,168.300	-297,067.900*	-525,236.200
	(3.912)	(5.455)	(4.804)	(381,745.600)	(140,474.300)	(320,428.300)
Constant	142.714***	64.286***	207.000***	14,519,231.000***	1,497,293.000***	16,016,524.000***
	(6.389)	(8.908)	(7.845)	(623,388.000)	(229,393.600)	(523,257.300)
Observations	10	10	10	10	10	10
R^2	0.450	0.578	0.786	0.517	0.843	0.360
Adjusted R^2	0.175	0.367	0.679	0.275	0.764	0.039
Residual Std. Error (df = 6)	5.345	7.453	6.563	521,563.800	191,924.400	437,788.400
F Statistic (df = 3; 6)	1.635	2.743	7.345**	2.139	10.711***	1.123
Note:	*$^{*}p<0.1$; ****$p<0.05$**; $^{***}p<0.01$*					

7.2.3 Distributional Analysis

The distributional analysis aims to track the demographic changes of residents along the treatment corridor, control corridor and the city as a whole before and after the bike lane installation to examine any potential equity outcomes of the bike lane installation on the Franklin Avenue corridor. This analysis is conducted using the LEHD dataset, where income indicators are available for a longer time period (covering both the pre- and post-construction periods), while gender, race and education indicators are only available starting in 2009.

7.2.3.1 Income

The income-level composition remained relatively constant before 2011. In 2012, high-income employment decreased slightly and recovered after that. There was generally a smaller amount of high-income employment on the control portion of the Franklin Avenue corridor compared to the treatment corridor, and the percentage of high-income employment increased after 2013. However, as discussed previously, LEHD income brackets are not indexed by inflation, which may contribute to these changes we observed. In general, there was not much difference in income composition change between the treatment and control corridors after the bike lane installation on Franklin Avenue.

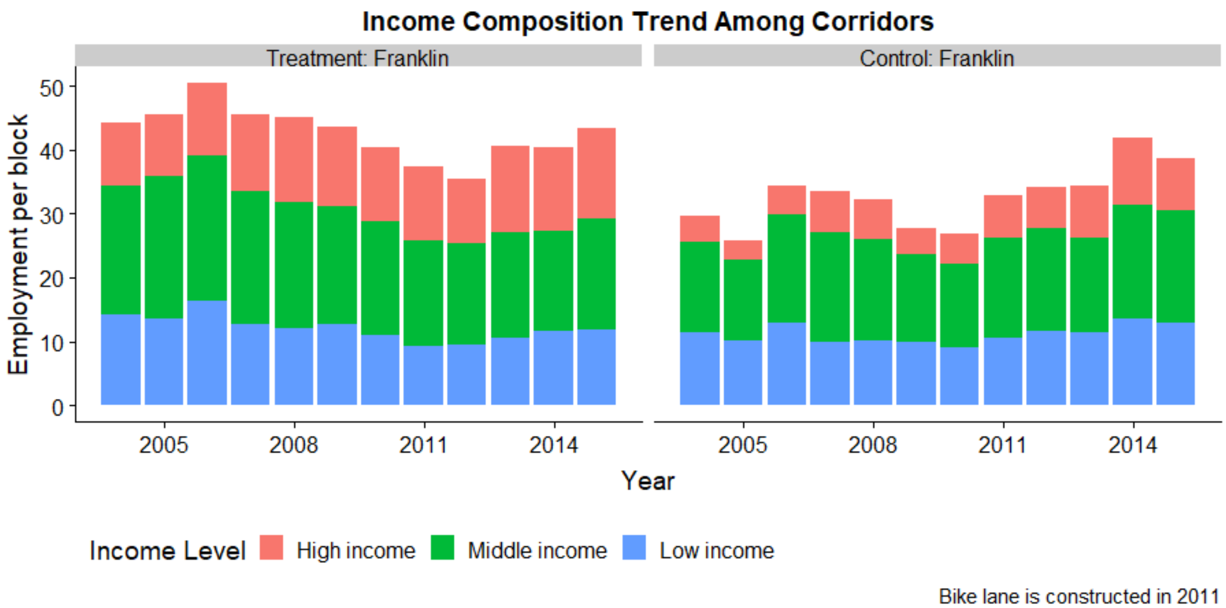


Figure 7-26. Franklin Avenue Income Employment Level Composition Trend

7.2.3.2 Race

7.2.3.2.1 Employment

In terms of employment racial composition, there were higher levels of black employment in both the treatment and control corridors compared to the city average. The percentage of black employment decreased sharply on the treatment corridor, combined with a corresponding increase in white employment. During the same period, the employment racial composition of white and black employment did not experience much change on the control corridor. This preliminary analysis shows some evidence that there may be racial gentrification in employment on the improved Franklin Avenue corridor following the bike lane installation. Although there was a large increase in American Indian employment and a decrease in Asian employment in the control corridor compared with the treatment corridor, white and black employment were still the dominant races on those two corridors.

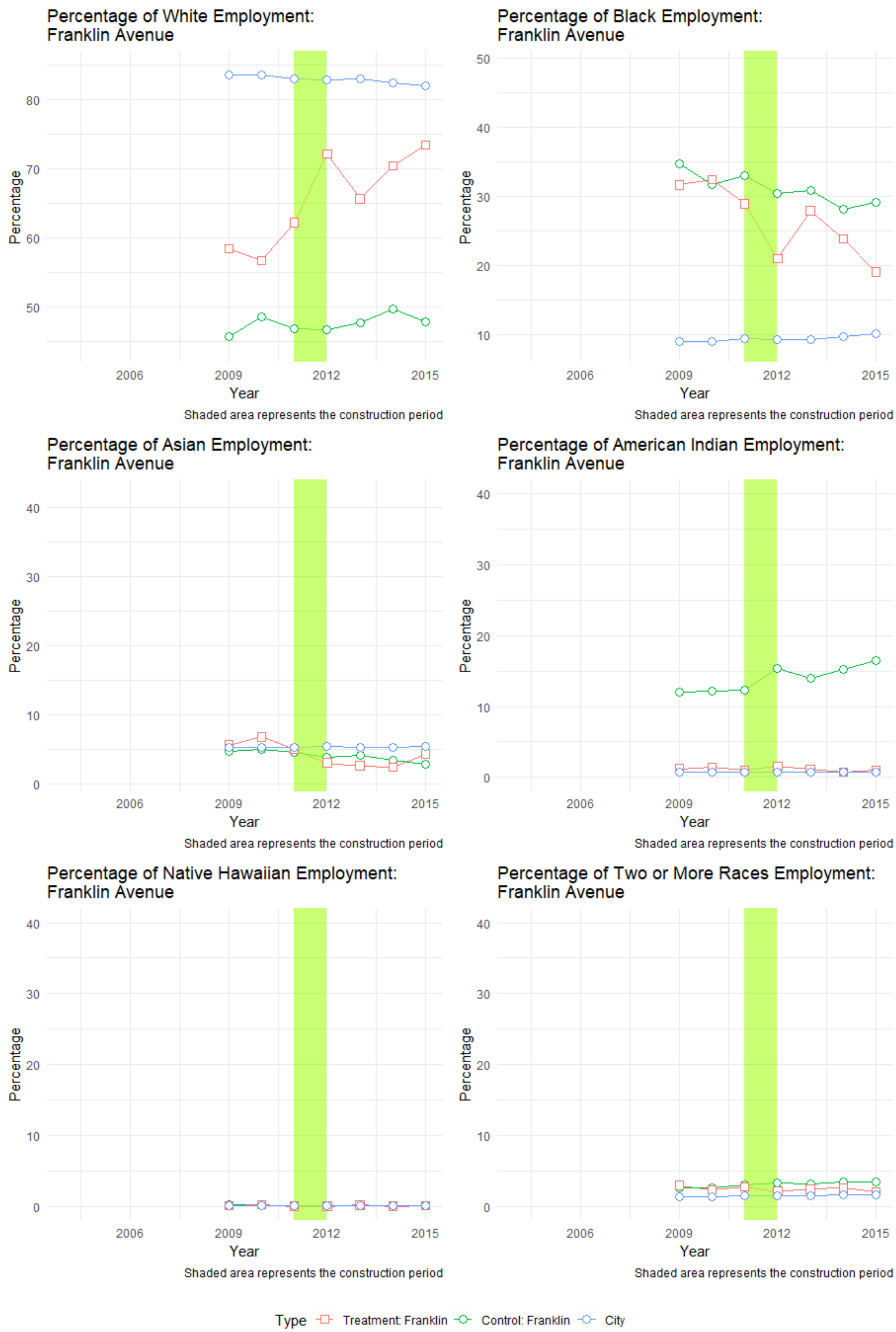


Figure 7-27. Franklin Avenue Employment Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

The table below shows the similar results as the above graphs, that the employment racial composition on the treatment corridor experienced an apparent increase in white employment and decreases in other races.

Table 7-33. Franklin Avenue Employment Racial Composition Percentage Change (in percentage)

	Treatment: Franklin	**Control: Franklin**	**City**
White	4.51	0.54	-0.30
Black	-8.52	-2.91	1.71
American Indian	-1.05	8.34	-0.29
Asian	-3.23	-9.16	0.66
Hawaiian	NA	15.58	4.51
Two or more races	-6.68	3.26	3.94

Note: These percentage changes are calculated as the average annual percentage change between 2009 and 2015.

7.2.3.2.2 Residents

Compared with employment racial composition, there was less racial composition change in residents living on the treatment corridor. During the analysis time period, the percentage of black residents decreased followed by an increase in white residents along both the treatment and control corridors. These trends may be indicative of displacement of certain groups of residents following the street improvement, but this effect is much less apparent than the trends of employment displacement.

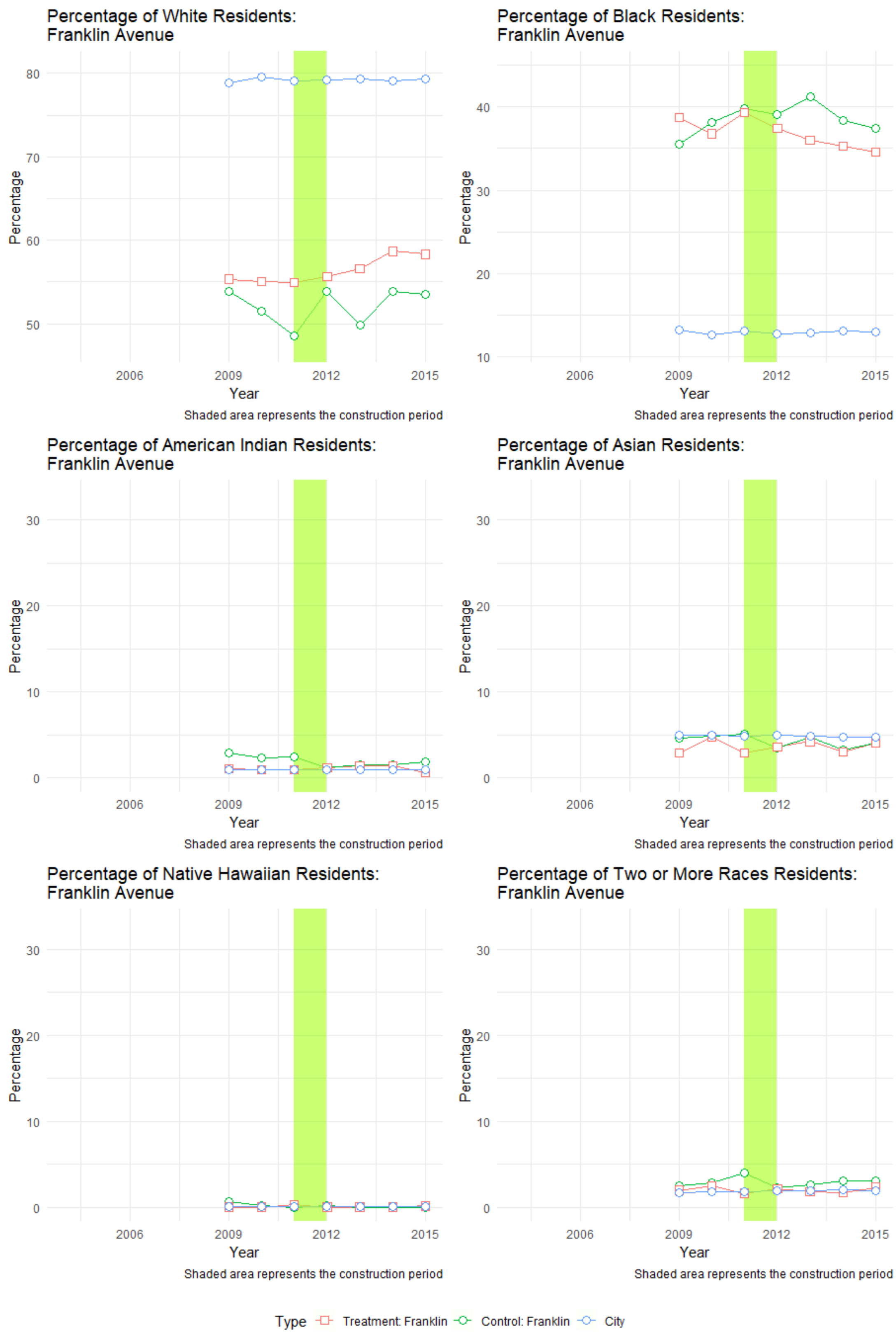


Figure 7-28. Franklin Avenue Residents Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

From the table below, we found similar results as the above graphs, that the percentage of white residents increased slightly and black residents decreased slightly in both the treatment and control corridors and the city level.

Table 7-34. Franklin Avenue Residents Racial Composition Percentage Change (in percentage)

	Treatment: Franklin	**Control: Franklin**	**City**
White	1.54	2.58	0.06
Black	-3.01	-1.53	-0.32
American Indian	-8.87	-6.16	-0.91
Asian	9.63	-4.95	-0.42
Hawaiian	-10.67	NA	1.67
Two or more races	10.47	-6.00	1.28

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

7.2.3.3 Education

7.2.3.3.1 Employment

In terms of education attainment, the selected corridors have much less higher-educated employment, but more lower-level educated employment compared to the city average levels. In addition, the percentage of bachelor's or above employment decreased in the treatment corridor, while employment in all three other categories increased. These trends are generally similar across all corridors as well as in the city of Minneapolis.

The percentage change table (Table 7-35) below shows a similar trend as the graph. The treatment corridor experienced generally similar employment educational attainment change as the city and control corridor.

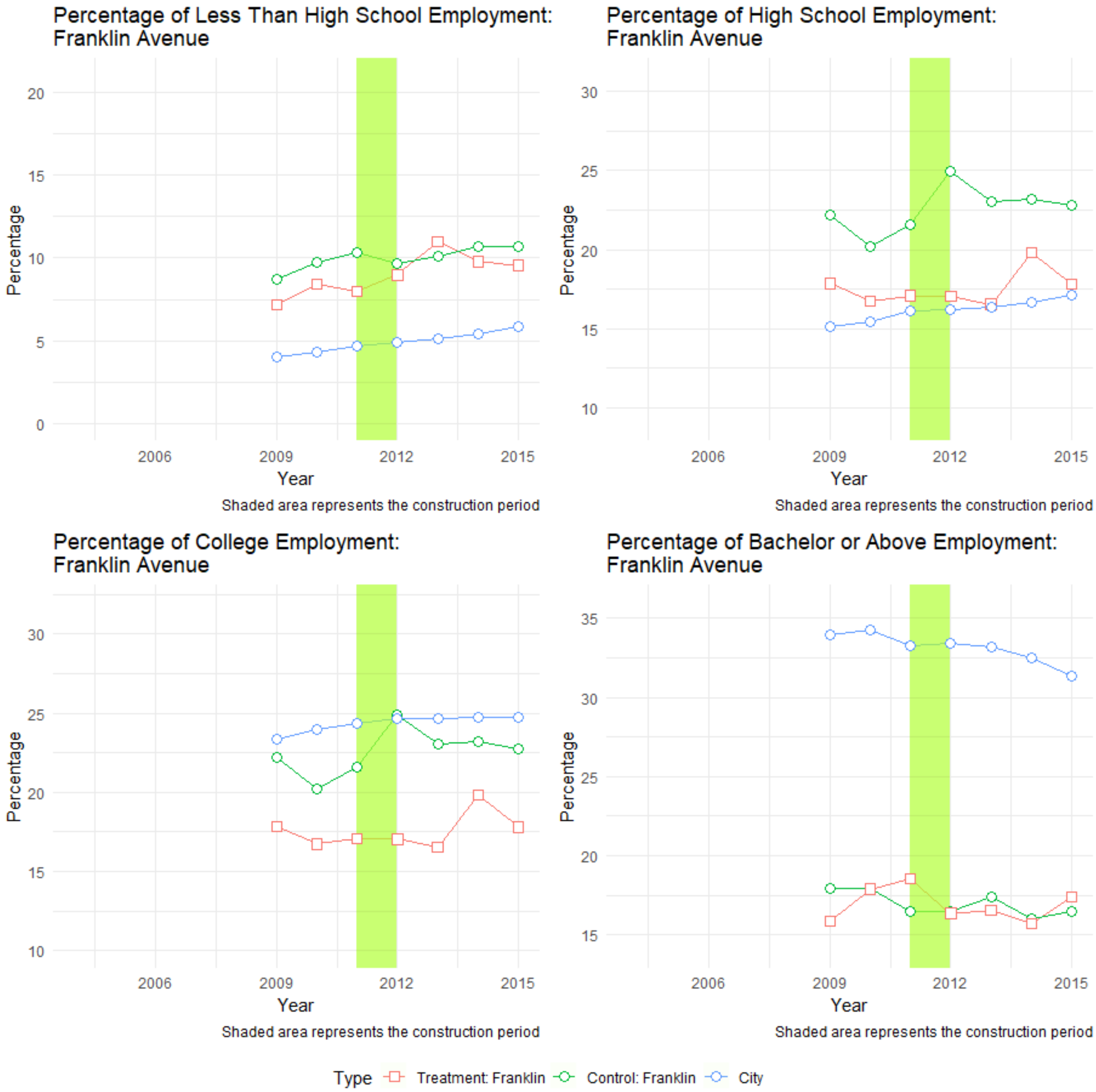


Figure 7-29. Franklin Avenue Employment Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 7-35. Franklin Avenue Employment Education Level Composition Percentage Change (in percentage)

	Treatment: Franklin	**Control: Franklin**	**City**
Less than high school	4.92	0.79	6.43
High school	1.07	1.40	1.53
College	1.07	1.40	0.42
Bachelor's or above	-1.55	0.07	-1.46

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

7.2.3.3.2 Residents

In terms of residents' education level, the trend shows more fluctuation than the employment education-level trends. In the treatment corridor, more less-educated residents moved in and more higher-educated residents moved out compared to the city in general and the control corridor. However, due to the fuzziness of LEHD data, fluctuations at this geographical scale are not greatly indicative of actual change.

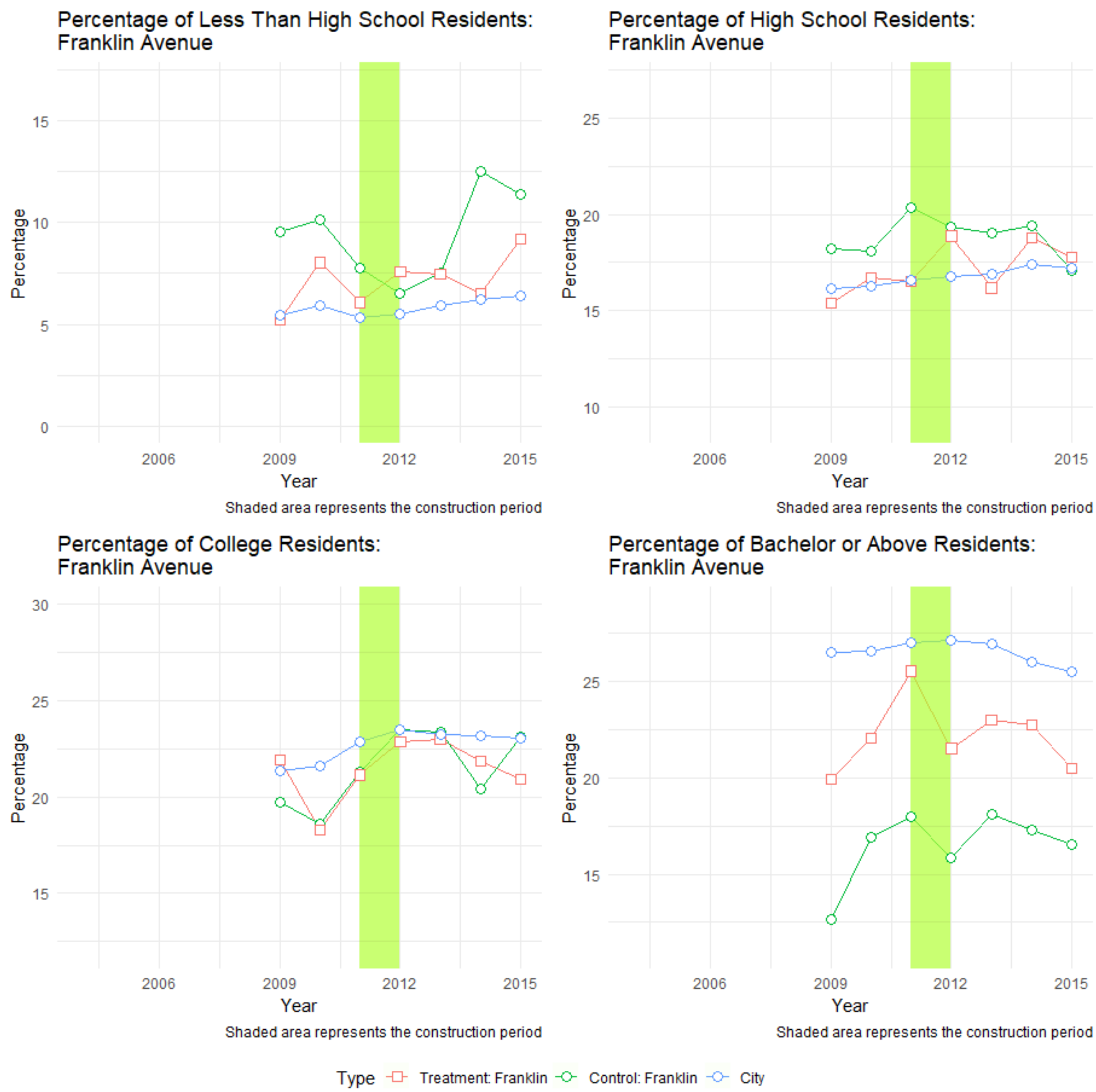


Figure 7-30. Franklin Avenue Residents Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 7-36. Franklin Avenue Residents Education Level Composition Percentage Change (in percentage)

	Treatment: Franklin	Control: Franklin	City
Less than high school	12.83	11.70	4.99
High school	1.87	-3.95	0.97
College	-0.29	2.11	0.21
Bachelor's or above	-4.93	-2.02	-1.42

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

7.2.3.4 Gender

In terms of gender, there was a significant drop in female employment after the street improvement on the treatment corridor. However, there was not much change in the residential gender composition between the bike lane construction years of 2011 and 2015.

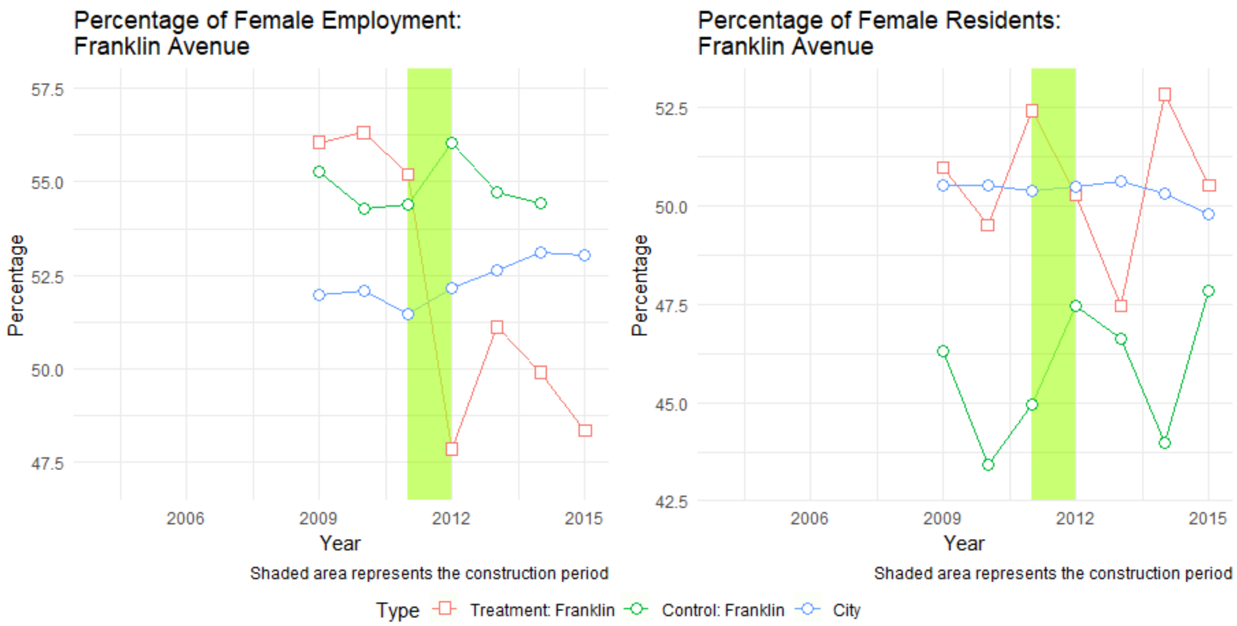


Figure 7-31. Franklin Avenue Gender Composition Trend

In summary, our distributional analysis finds that construction of the bike lane on the Franklin Avenue corridor may have resulted in employment racial displacement of black and female populations. While this may be attributed to some type of industrial shift on the street improvement corridor, these results show the need for a deeper examination of the potential equity outcomes here.

7.2.4 Franklin Avenue Corridor Summary

We used three different data sources, LEHD employment data, QCEW data and NETS employment and sales revenue data, to analyze the economic and equity impacts of street improvement on the Franklin Avenue corridor. Each of these data sources was analyzed using the aggregated trend analysis, DID estimation and ITS estimation approaches, and we were able to conclude that:

- Retail employment growth is observed in the street improvement segment of Franklin Avenue at a faster rate than the control corridor, based on LEHD data. In addition, QCEW data indicates total wages in the retail sector also appear to be growing at a faster pace in the improvement corridor, possibly indicating a shift in the type of retail businesses that are located in this area.
- Although retail employment increased after the bike lane installation, the evidence from the ITS approach from the two data sources shows a statistically non-significant causal relationship between the bike lane installation and employment growth.
- LEHD data shows food employment greatly increased two years after the bike lane installation, exceeding the growth rate of both the control corridor and greater city trends. Both the trend analysis and ITS approach show a positive trend.
- Three data sources led to slightly different findings, similarly as the other corridor in Minneapolis. This might be due to the disparity of included industries or geographical scales in the data collection process.
- There are mixed impacts on retail services, but generally no positive impact on the food industry according to different data sources and different methods.
- The distributional analysis results show that construction of a bike lane on the Franklin Avenue corridor may have resulted in employment racial displacement of black and female populations. While this may be attributed to some type of industrial shift on the street improvement corridor, these results show the need for a deeper examination of the potential equity outcomes here.

8.0 CASE EXPLORATION: MEMPHIS

8.1 MADISON AVENUE

Madison Avenue, located in the Midtown district, received a buffered bike lane in 2011. The control corridors are Union Avenue and Cooper Street, close to the treatment corridor in Midtown; Highland Street, located to the southeast of the district; and Jackson Avenue on the north side.

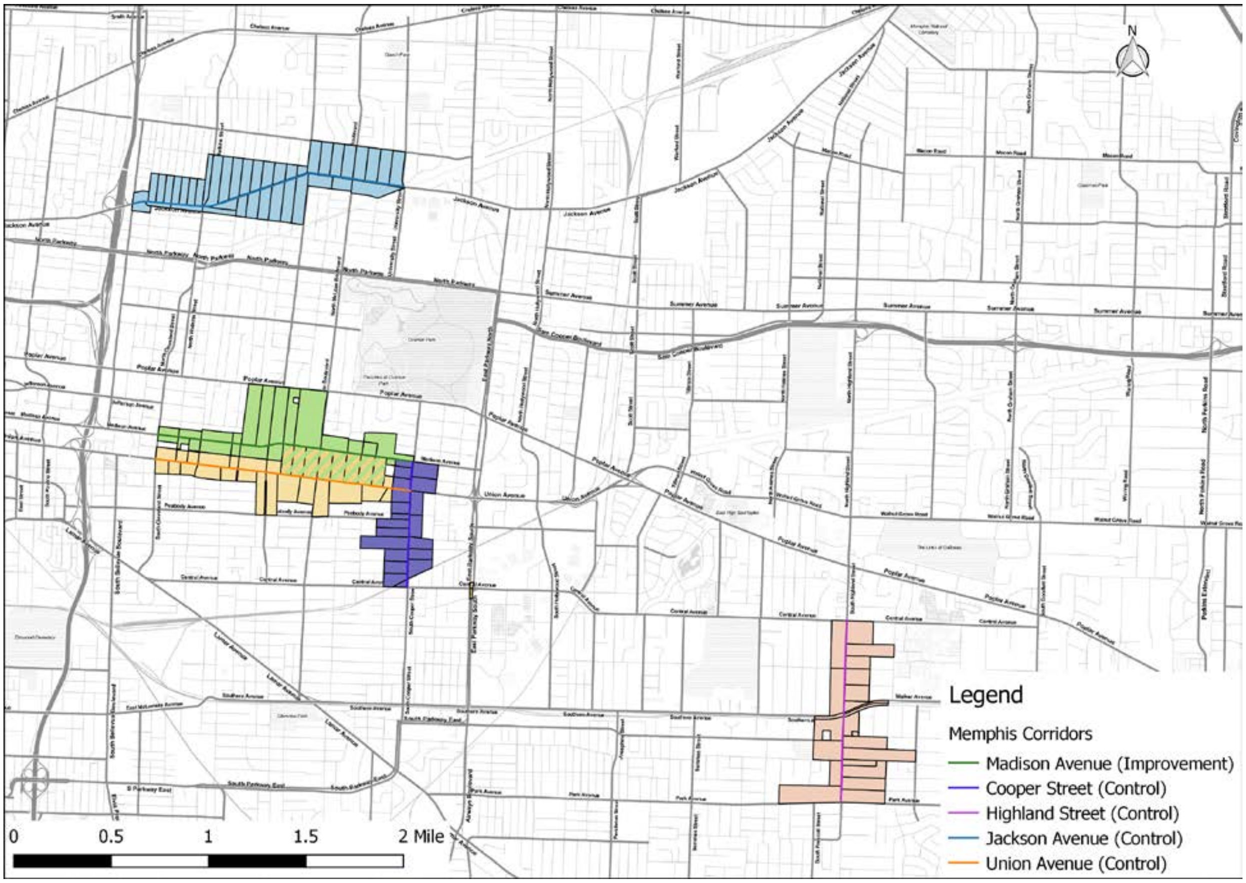


Figure 8-1. Memphis Madison Avenue Corridors Map

8.1.1 Corridor Selection

Comparing total employment among corridors, we find the Highland Street Corridor has very similar total employment with the Madison Avenue corridor. While the Union Avenue corridor has much more total employment than Madison Avenue, it has similar levels of retail and food employment as the treatment corridor. Jackson Avenue appears to be less comparable to the treatment corridor, since it has much lower amount of economic activity.

Table 8-1. Comparison of Business Jobs per Block Percentiles among Madison Corridors

	Tot Emp.	Retail Emp.	Food Emp.	Tot (%)	Retail (%)	Food (%)
Madison Ave.	68	16	17	65-70	80-85	80-85
Cooper St.	124	6	12	75-80	65-70	75-80
Highland St.	77	10	25	70-75	70-75	85-90
Jackson Ave.	8	2	1	25-30	50-55	45-50
Union Ave.	140	12	16	95-100	75-80	80-85

The t-tests show that the mean business employment and food employment per block on the Jackson Avenue corridor to be significantly different than the treatment Madison Avenue corridor. Additionally, we performed a second set of t-tests on the business/service employment ratios between the two corridors. In this case, all of the comparison corridors t-tests came back non-significant, indicating the corridors have a similar structure of business versus service jobs.

The following table shows a summary of the corridor comparison analysis for all treatment and control corridor groups, with nine comparability indicators for each group. We determined that the corridor groups met a sufficient number of comparability checks, though a few corridors have very low retail or food employment at the block level. We find that the Cooper Street, Highland and Union control corridors are very similar and comparable in most aspects to the Madison Avenue improvement corridor, except for some of the transportation and geography indicators. However, Jackson Avenue was determined to be not quite comparable to the treatment corridor, since it has a much smaller amount of business-related employment and is further away in

Treatment corridor	**Indicator**		**Madison Avenue**			
Control corridor			Cooper	Highland	Jackson	Union
Transportation / Geography	Geographic proximity		□	X	X	□
	Street classification		□	□	□	X
	Role in street network		□	□	□	X
Business Activity	Job density percentile	Retail	□	□	X	□
		Food	□	□	X	□
	Share of business jobs		□	□	□	□
	Employment growth rate	Retail	X	□	□	□
		Food	□	□	□	□

terms of geographic proximity. Therefore, we excluded the Jackson Avenue control corridor from further analysis.

Table 8-2. Study and Comparison Selection Criteria (Madison Avenue)

8.1.2 Economic Outcome Analysis

8.1.2.1 LEHD Data

8.1.2.1.1 Aggregated Trend Analysis

There is a slight increase in retail employment right after the bike lane installation in 2011 on the Madison Avenue corridor, but this is followed with subsequent decreases in retail employment. This performance is better than one control corridor, Union Avenue, but worse than the other two control corridors, Highland Street and Cooper Street. In addition, city-wide retail employment performed better than the treatment corridor, indicating that the street improvement on Madison might have had a negative impact on retail employment.

However, when we turned our attention to the food service sector, we observed a significant drop right after the bike lane installation, but a dramatic recovery after two years. The performance of the food sector on the control corridors is mixed; the Cooper corridor experienced an unexpected dramatic increase after 2011, while the other two corridors either grew slowly or had significant drops after 2011 and the city-level trends remained consistently flat. This aggregated trend analysis of LEHD data points to a positive impact of the bike lane installation on Madison Avenue on food employment. Because the three control corridors are relatively different it is difficult to draw conclusions from the aggregated trend analysis, and we believe that the following econometric analyses may provide a better understanding of the impacts of the Madison bike lane corridor.

Table 8-3. Madison Corridor Trend Analysis Summary Table (LEHD)

	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
Area	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
LEHD: [employment]												
Treatment	494	3.41%	-8.30%	8.39%	-11.61%	-3.84%	510	7.90%	-20.78%	2.48%	32.85%	4.85%
Control: Union	399	10.45%	-11.28%	2.54%	12.95%	1.40%	565	-2.20%	28.32%	-2.34%	12.01%	12.66%
Control: Highland	190	1.63%	-30.00%	11.28%	10.81%	-2.64%	421	-3.04%	68.65%	3.24%	-42.84%	9.68%
Control: Cooper	103	-3.25%	11.65%	9.57%	-11.90%	3.10%	225	-3.44%	44.89%	18.10%	23.64%	28.87%

1 Baseline is defined as the average of the three years prior to the construction year;
2 Pre-growth rate is defined as the average of the baseline annual growth rates;
3 Post-growth rate is defined as the average annual growth rate of three time points after the construction year.

8.1.2.1.2 Difference-in-Difference (DID) Analysis

The DID estimators using LEHD data are non-significant for all three models, indicating there is no impact on business employment.

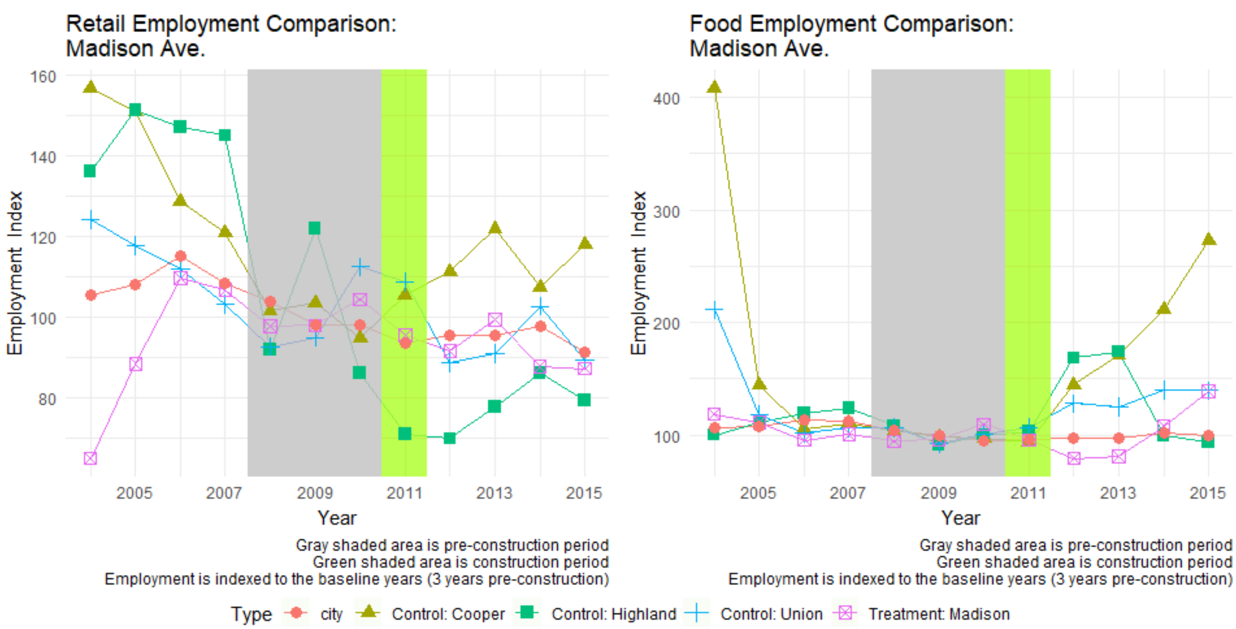


Figure 8-2. Madison Avenue Employment Comparison (LEHD)

8.1.2.1.3 Interrupted Time Series (ITS) Analysis

ITS analysis of LEHD data on Madison Avenue shows statistically significant results for food employment. It indicates that the bike lane installation caused the food employment to drop significantly in level (by 1,152) after the project installation, but with greater slope change, a growth of 115 more employment annually than the pre-installation period. This is consistent with the aggregated trend analysis plots. Due to a limited number of data points and growth in food employment after the bike lane installation, the fitted post-interruption line must have a lower starting point (intercept) coupled with a steep slope. We believe that these results may become more interpretable as more time passes and more data can be obtained, to generate a more accurate estimation of both the intercept and slope parameters in the ITS estimation.

Table 8-4. Madison Avenue DID Regression Results (LEHD Data)

Madison Ave. Corridor Difference-in-Difference Estimates

	Dependent variable:	
	CNS07 Retail Emp.	CNS18 Food Emp.
TypeControl: Cooper	-348.500***	-196.250**
	(22.577)	(78.337)
TypeControl: Highland	-246.750***	-71.875
	(22.577)	(78.337)
TypeControl: Union	-40.750*	143.500*
	(22.577)	(78.337)
prepost	-20.625	-4.625
	(27.652)	(95.943)
DID estimator: Cooper	14.75	127.5
	(39.105)	(135.684)
DID estimator: Highland	-56.5	117.375
	(39.105)	(135.684)
DID estimator: Union	-40.5	91.5
	(39.105)	(135.684)
Constant	472.875***	523.625***
	(15.965)	(55.393)
Observations	48	48
R^2	0.925	0.434
Adjusted R^2	0.912	0.335
Residual Std. Error (df = 40)	45.155	156.674
F Statistic (df = 7; 40)	70.415***	4.387***
Note:		p<0.1; p<0.05; p<0.01

8.1.2.2 Sales Tax Data

8.1.2.2.1 Aggregated Trend Analysis

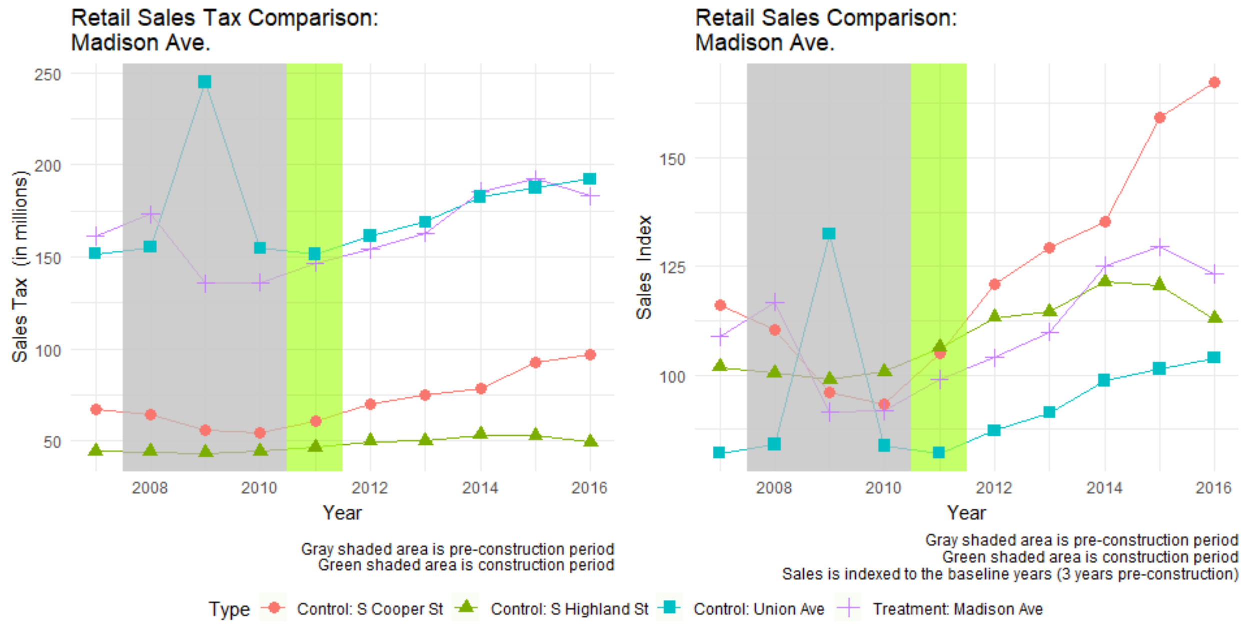


Figure 8-3. Madison Avenue Sales Revenue Comparison (Sales Tax Data)

Compared with its control corridors, the Madison Avenue treatment corridor experienced many more establishments opening after the street improvement. Correspondingly, the indexed retail sales also increased faster than all control corridors except for Cooper Street. However, if we examined the amount of sales per establishment, the treatment corridor appears to track the control corridors closely. Therefore, we can conclude that the bike lane installation on Madison Avenue had a positive impact on retail sales, mostly due to more establishments opening along the corridor.

Table 8-5. Madison Avenue ITS Regression Results (LEHD Data)

Madison Ave. Corridor Interrupted Time Series Estimates

	Dependent variable:	
	CNS07 Retail Emp.	CNS18 Food Emp.
Yearly trend	14.679	-10.464
	(8.921)	(7.065)
Level change	174.579	-1,152.114***
	(276.696)	(219.143)
Slope change	-26.979	115.264***
	(27.35)	(21.661)
Constant	406.821***	570.714***
	(45.047)	(35.677)
Observations	12	12
R^2	0.29	0.78
Adjusted R^2	0.024	0.698
Residual Std. Error (df = 8)	57.812	45.787
F Statistic (df = 3; 8)	1.091	9.472***
Note:		p<0.1; p<0.05; p<0.01

Table 8-6. Madison Corridor Trend Analysis Summary Table (Sales Tax Data)

	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
Area	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
Sales: [sales revenue, 1,000,000$]												
Treatment	148.3	-10.64%	3.92%	5.69%	13.95%	7.85%	-	-	-	-	-	-
Control: Union	185.0	10.47%	-12.86%	4.75%	8.08%	-0.01%	-	-	-	-	-	-
Control: Highland	43.8	0.22%	13.15%	1.16%	6.16%	6.82%	-	-	-	-	-	-
Control: Cooper	58.1	-7.94%	20.97%	6.83%	4.62%	10.81%	-	-	-	-	-	-

1 Baseline is defined as the average of the three years prior to the construction year;
2 Pre-growth rate is defined as the average of the baseline annual growth rates;
3 Post-growth rate is defined as the average annual growth rate of three time points after the construction year.

8.1.2.2.2 Difference-in-Difference (DID) Analysis

Similarly, two DID models, using retail gross sales and number of establishments of the sales tax data as dependent variables, were estimated. The DID estimators are non-significant for both models, indicating there is no particular impact pattern on retail sales and business establishment numbers.

Table 8-7. Madison Avenue DID Regression Results (Sales Data)

Madison Ave. Corridor Difference-in-Difference Estimates		
	Dependent variable:	
	gross_sales	business
TypeControl: Cooper	-90,151,456***	-58.577***
	(11,297,117)	(3.382)
TypeControl: Highland	-106,100,132***	-40.597***
	(11,297,117)	(3.382)
TypeControl: Union	20,952,570*	-5.194
	(11,297,117)	(3.382)
prepost	24,907,011.**	3.05
	(11,297,117)	(3.382)
DID estimator: Cooper	-2,714,756	3.567
	(15,976,536)	(4.783)
DID estimator: Highland	-18,361,986	-1.778
	(15,976,536)	(4.783)
DID estimator: Union	-18,079,759	0.9
	(15,976,536)	(4.783)
Constant	150,648,061.***	94.844***
	(7,988,268)	(2.392)
Observations	40	40
R^2	0.925	0.962
Adjusted R^2	0.909	0.954
Residual Std. Error (df = 32)	17,862,311	5.348
F Statistic (df = 7; 32)	56.468***	116.551***
Note:		*p<0.1; p<0.05;* p<0.01

8.1.2.2.3 Interrupted Time Series (ITS) Analysis

ITS analysis of the sales tax data shows that the gross sales increased $15,288,908 more every year than pre-installation on Madison Avenue, indicated by the slope change parameter of the gross sales mode. When we estimated the impact of the street improvement on the number of establishments, we found that the level change parameter is negative, while the slope change parameter is positive. It means that the bike lane installation on the treatment corridor brought about a reduction of 57 establishments, but eight more in terms of the annual growth rate. Similar to the LEHD employment models, the estimation will be more smooth and accurate with longer time data points collected in the future. These ITS analysis results generally point to positive impacts on retail sales from the bike lane installation on Madison Avenue.

Table 8-8. Madison Avenue ITS Regression Results (Sales Data)

Madison Ave. Corridor Time Series Estimates		
	Dependent variable:	
	gross_sales	business
Yearly trend	-6,620,538	-1.065
	(3,937,011)	(1.718)
Level change	-64,301,562	-57.938***
	(34,547,128)	(15.078)
Slope change	15,288,908**	8.289**
	(5,567,774)	(2.43)
Constant	170,509,676***	98.038***
	(13,057,587)	(5.699)
Observations	10	10
R^2	0.747	0.759
Adjusted R^2	0.62	0.638
Residual Std. Error (df = 6)	12,449,921	5.434
F Statistic (df = 3; 6)	5.894**	6.282**
Note:		*p<0.1; p<0.05;* p<0.01

8.1.2.3 QCEW Data

8.1.2.3.1 Aggregated Trend Analysis

Using QCEW data on employment levels, we found large jumps in retail employment on the corridor after the bike lane installation. The retail employment trends on the corresponding control corridors, however, are similar to that of Madison Avenue. This indicates that additional econometric analyses such as DID or ITS may be required in order to identify the effects of construction on employment growth. In terms of food service industry employment, there were also large jumps on all corridors after construction. While food service employment on the control corridors slightly decreased after 2013, the treatment corridor has steadily maintained its food employment levels.

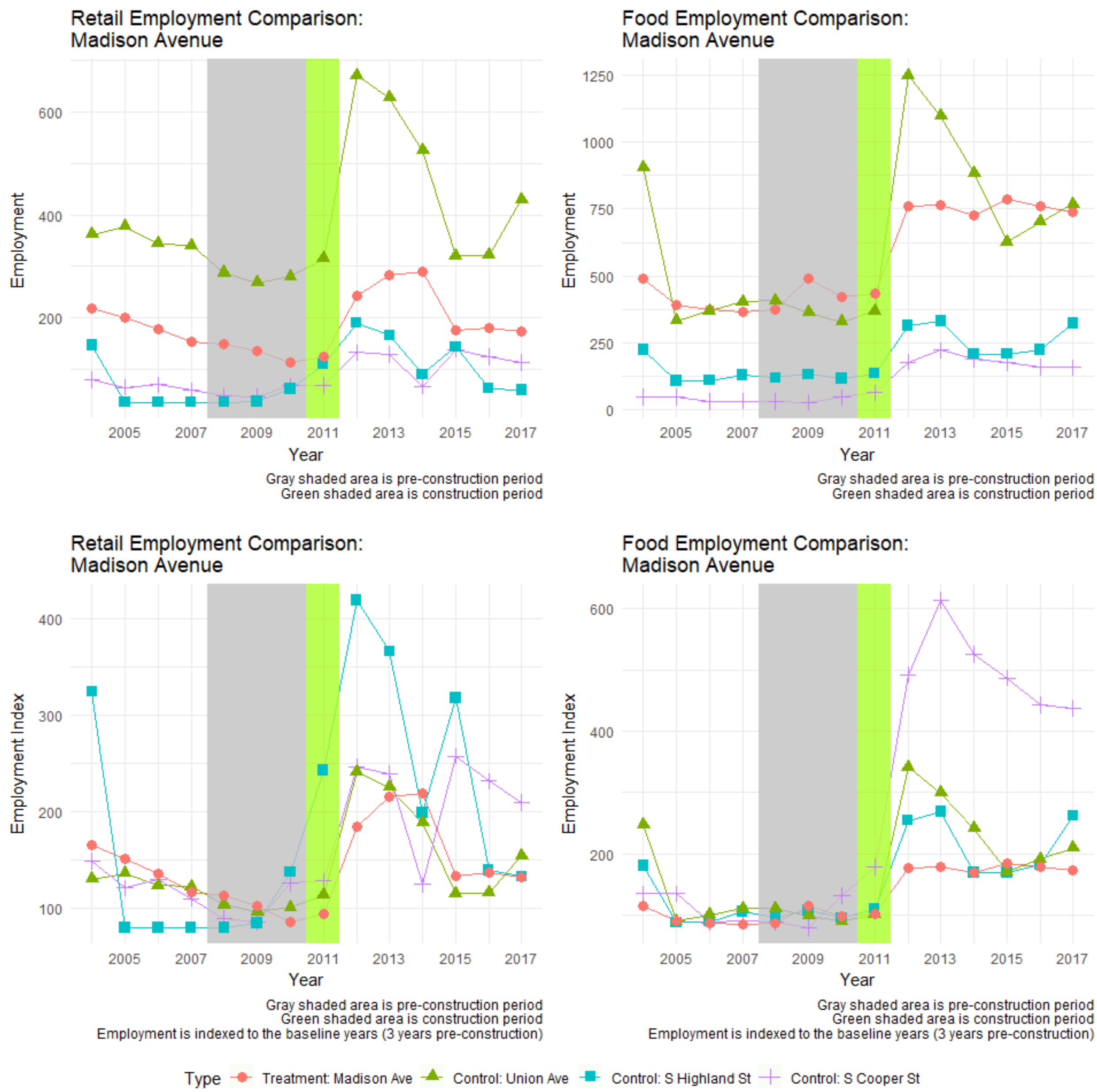


Figure 8-4. Madison Avenue Employment Comparison (QCEW)

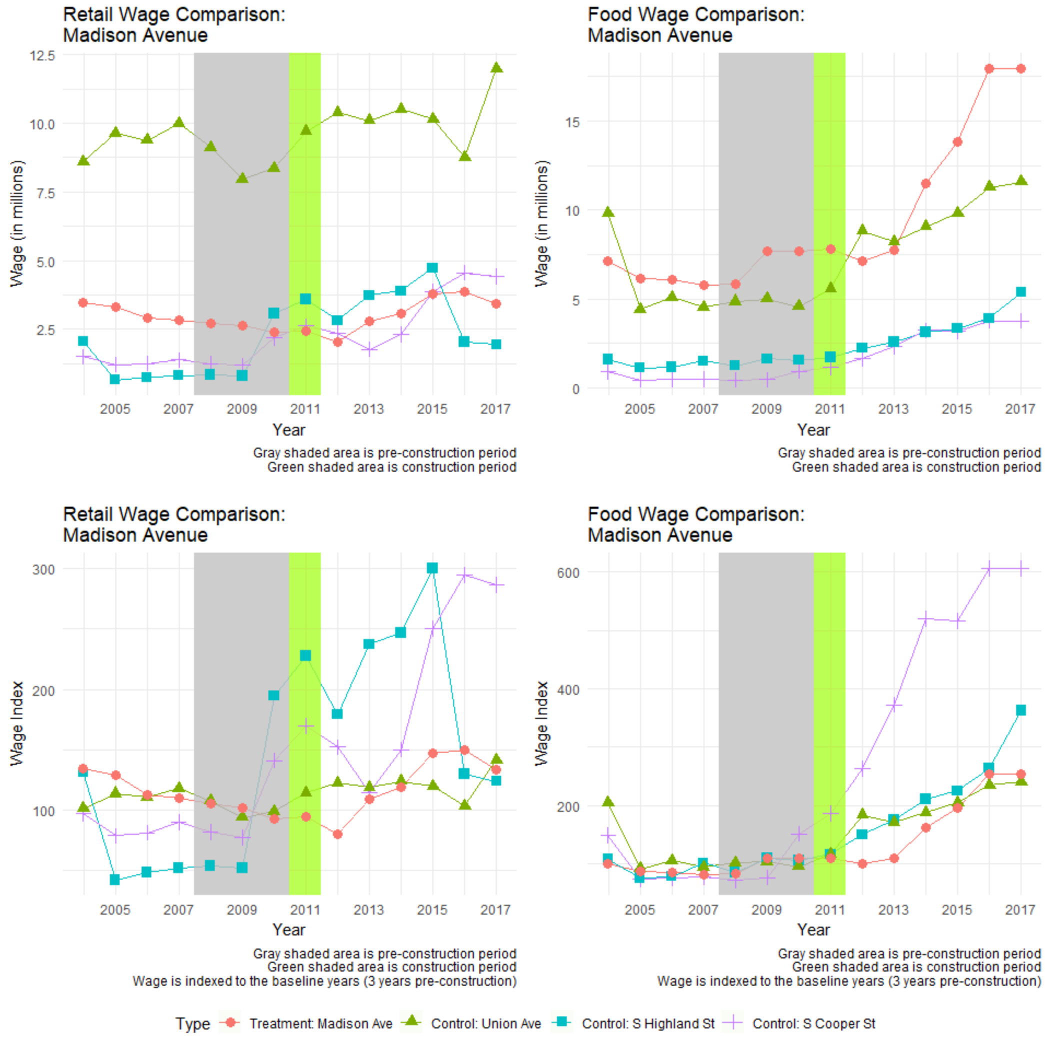
Table 8-9. Madison Corridor Trend Analysis Summary Table (QCEW)

Area	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
QCEW: [employment]												
Treatment	132	-12.85%	84.85%	16.39%	1.76%	34.33%	428	8.14%	77.34%	0.79%	-5.10%	24.34%
Control: Union	279	-1.05%	140.86%	-6.55%	-16.40%	39.30%	366	-10.09%	241.53%	-12.24%	-19.42%	69.96%
Control: Highland	45	34.36%	322.22%	-12.63%	-45.78%	87.94%	124	-0.22%	154.03%	5.40%	-37.05%	40.79%
Control: Cooper	54	21.83%	146.30%	-3.01%	-48.06%	31.74%	36	28.07%	397.22%	24.58%	-14.35%	135.82%

1 Baseline is defined as the average of the three years prior to the construction year;
2 Pre-growth rate is defined as the average of the baseline annual growth rates;
3 Post-growth rate is defined as the average annual growth rate of three time points after the construction year.

With respect to retail wages, we observed a large jump in total wages on the treatment corridor after the street improvement project; however, this trend was similar in the control corridors. Similarly, in the food service industry there were jumps in overall wage levels on all corridors after the construction period. Moreover, unlike other control corridors where wage levels fluctuated after construction, wage levels on the treatment corridor of Madison Avenue maintained a stable level.

Figure 8-5. Madison Avenue Wage Comparison (QCEW)



8.1.2.3.2 Difference-in-Difference (DID)Analysis

The results of the DID analysis on QCEW employment data indicate that the corridor shows some mixed results depending on which control corridor was used for comparison. In the cases of the Cooper Street and Highland Street control corridors, the difference in terms of food and business employment are negative and significant. This means that the Madison Avenue treatment corridor experienced positive effects of the infrastructure construction on food sector employment and on overall business employment. On the other hand, the difference in terms of retail and business employment of the Union Avenue control corridor exhibit a statistically significant and positive effect, meaning that the Madison Avenue treatment corridor experienced more negative outcomes in retail and business employment compared to the Union Avenue corridor.

Table 8-10. Madison Avenue DID Regression Results (QCEW Data, Employment)

Madison Ave. Corridor Difference-in-Difference Estimates (Employment)

	Dependent variable:		
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.
TypeControl: S Cooper St	-95.875***	-375.375***	-471.250***
	(30.778)	(56.037)	(79.335)
TypeControl: S Highland St	-96.375***	-282.250***	-378.625***
	(30.778)	(56.037)	(79.335)
TypeControl: Union Ave	163.125***	17.75	180.875**
	(30.778)	(56.037)	(79.335)
prepost	65.667*	339.000***	404.667***
	(33.244)	(60.527)	(85.692)
TypeControl: S Cooper St:prepost	-11.125	-199.458**	-210.583*
	(47.014)	(85.599)	(121.187)
TypeControl: S Highland St:prepost	-9.458	-205.250**	-214.708*
	(47.014)	(85.599)	(121.187)
TypeControl: Union Ave:prepost	95.208**	113.583	208.792*
	(47.014)	(85.599)	(121.187)
Constant	159.000***	417.500***	576.500***
	(21.763)	(39.624)	(56.099)
Observations	56	56	56
R^2	0.845	0.873	0.877
Adjusted R^2	0.822	0.854	0.859
Residual Std. Error (df = 48)	61.556	112.075	158.671
F Statistic (df = 7; 48)	37.315***	46.995***	48.866***
Note:			*p<0.1; p<0.05;* p<0.01

DID analysis of the QCEW wage data shows that the differences for the Cooper Street and Highland Street corridors are significant, while those for the Union Avenue corridor do not show statistically significant effects. The results for Cooper Street and Highland Street, however, are equivocal. On one hand, the differences for total wages in the retail sector are significant and positive; on the other hand, those for total wages in the food industry are significant and negative. These results indicate that the Madison Avenue treatment corridor has positive effects on wages in the food industry, while it affects retail wages negatively. The differences for business wages as a whole, however, are

Table 8-11. Madison Avenue DID Regression Results (QCEW Data, Wage)

Madison Ave. Corridor Difference-in-Difference Estimates (Wage)

	Dependent variable:		
	CNS07 Retail Wage	CNS18 Food Wage	business 'Business' Wage
TypeControl: S Cooper St	-1,259,970***	-6,090,435***	-7,350,405***
	(441,902.2)	(918,457.4)	(1,089,526)
TypeControl: S Highland St	-1,261,179***	-5,316,280***	-6,577,459***
	(441,902.2)	(918,457.4)	(1,089,526)
TypeControl: Union Ave	6,252,991***	-1,276,678	4,976,313***
	(441,902.2)	(918,457.4)	(1,089,526)
prepost	332,869.5	5,920,253***	6,253,122***
	(477,309)	(992,047.4)	(1,176,823)
TypeControl: S Cooper St:prepost	1,307,796*	-3,604,991**	-2,297,195
	(675,016.8)	(1,402,967)	(1,664,279)
TypeControl: S Highland St:prepost	1,285,857*	-3,936,700***	-2,650,843
	(675,016.8)	(1,402,967)	(1,664,279)
TypeControl: Union Ave:prepost	885,488.6	-1,615,372	-729,883.6
	(675,016.8)	(1,402,967)	(1,664,279)
Constant	2,840,231***	6,759,229***	9,599,459***
	(312,472.1)	(649,447.5)	(770,411.4)
Observations	56	56	56
R^2	0.937	0.833	0.897
Adjusted R^2	0.928	0.809	0.882
Residual Std. Error (df = 48)	883,804.4	1,836,915	2,179,052
F Statistic (df = 7; 48)	102.048***	34.181***	59.967***
Note:			*p<0.1; p<0.05;* p<0.01

not significant.

To sum up, in the case of the DID analysis of QCEW data, there are different results when using different control corridors. Considering the aggregated trend analysis presented above with these DID results, we find that Union Avenue may also not be appropriate as a control corridor.

8.1.2.3.3 Interrupted Time Series (ITS) Analysis

The ITS analysis of QCEW data on Madison Avenue shows that the street improvement contributed significantly to the increase in the level of employment for both the retail and food industries, but does not show significant effects on the slope changes. When we utilize wages as the economic indicator, we find that both *prepost* and *ts_year:prepost* terms are significant for both the retail and food industries. In particular, the *prepost* coefficients are negative and the *ts_year:prepost* terms are positive. These results should be interpreted in combination with the aggregated trend analyses to ensure that these estimation results are not misinterpreted. Considering both results, the street improvement treatment has a negative effect on the level of total wages in the retail industry, but contributes to a positive slope change for wages at the same time. In other words, the treatment can contribute to the increase in retail wages in the long term, even though retail wages immediately decreased after the street improvement. In the cases of food and total business wages, the ITS analyses results infer that the street improvement on Madison Avenue may not negatively affect wage levels in the long run, although the coefficient is significant and negative, because of the large positive effect on the slope (growth) in food and business wages.

Table 8-12. Madison Avenue ITS Regression Results (QCEW Data, Employment)

Madison Ave. Corridor Interrupted Time Series Estimates (Employment)

	Dependent variable:		
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.
ts_year	-14.643***	1.524	-13.119
	(4.071)	(6.841)	(7.553)
prepost	253.431***	358.671**	612.102***
	(76.146)	(127.967)	(141.29)
ts_year:prepost	-7.414	-2.638	-10.052
	(7.506)	(12.614)	(13.928)
Constant	224.893***	410.643***	635.536***
	(20.556)	(34.546)	(38.142)
Observations	14	14	14
R^2	0.823	0.952	0.96
Adjusted R^2	0.77	0.938	0.948
Residual Std. Error (df = 10)	26.382	44.335	48.951
F Statistic (df = 3; 10)	15.471***	66.838***	80.414***
Note:			*p<0.1; p<0.05;* p<0.01

Table 8-13. Madison Avenue ITS Regression Results (QCEW Data, Wage)

Madison Ave. Corridor Interrupted Time Series Estimates (Wage)

	Dependent variable:		
	CNS07 Retail Wage	CNS18 Food Wage	business 'Business' Wage
ts_year	-151,107.7***	204,190.5	53,082.73
	(41,764.3)	(146,815.4)	(163,815.3)
prepost	-3,897,261***	-21,786,975***	-25,684,236***
	(781,226.8)	(2,746,272)	(3,064,265)
ts_year:prepost	459,816***	2,285,034***	2,744,850***
	(77,009.56)	(270,714.2)	(302,060.4)
Constant	3,520,215***	5,840,372***	9,360,587***
	(210,899.4)	(741,381.5)	(827,226.5)
Observations	14	14	14
R^2	0.804	0.962	0.96
Adjusted R^2	0.745	0.951	0.948
Residual Std. Error (df = 10)	270,663.6	951,472.6	1,061,644
F Statistic (df = 3; 10)	13.681***	84.817***	80.2***
Note:			*p<0.1; p<0.05;* p<0.01

8.1.2.4 NETS Data

8.1.2.4.1 Aggregated Trend Analysis

The following tables and figures present the employment and sales change before and after the street improvement on the Madison Avenue corridors using the NETS dataset. As described previously in the data section, economic data from two types of industry categories are presented here: Type I includes all retail and food service establishments on the abutting blocks of the corridor, and Type II includes a refined subset of establishments directly facing the corridor (block-face establishments). Since the treatment and control corridors in this particular scenario are neighboring streets parallel to each other, Type I block-level data on the two corridors may include overlapping establishments.

In terms of the Type I industry (directly corresponding to LEHD industry categories), there is no significant change before and after the street improvement in retail employment and sales. While there is a slight increase in retail employment and sales one year after the street improvement, this trend generally followed the city as a whole. In the case of the food service employment and sales, however, the trend was worse than the city, but similar to the trends of the Cooper Street control corridor.

In terms of the more refined Type II block-face-level establishments, the employment and sales trends generally followed similar patterns as the Type I employment and sales trends. There is a small increase in retail employment and sales; however, generally, the trend is stable regardless of the bike lane installation. The trend of food service employment and sales experienced some decreases right after the street improvement, but this is also similar to one control corridor.

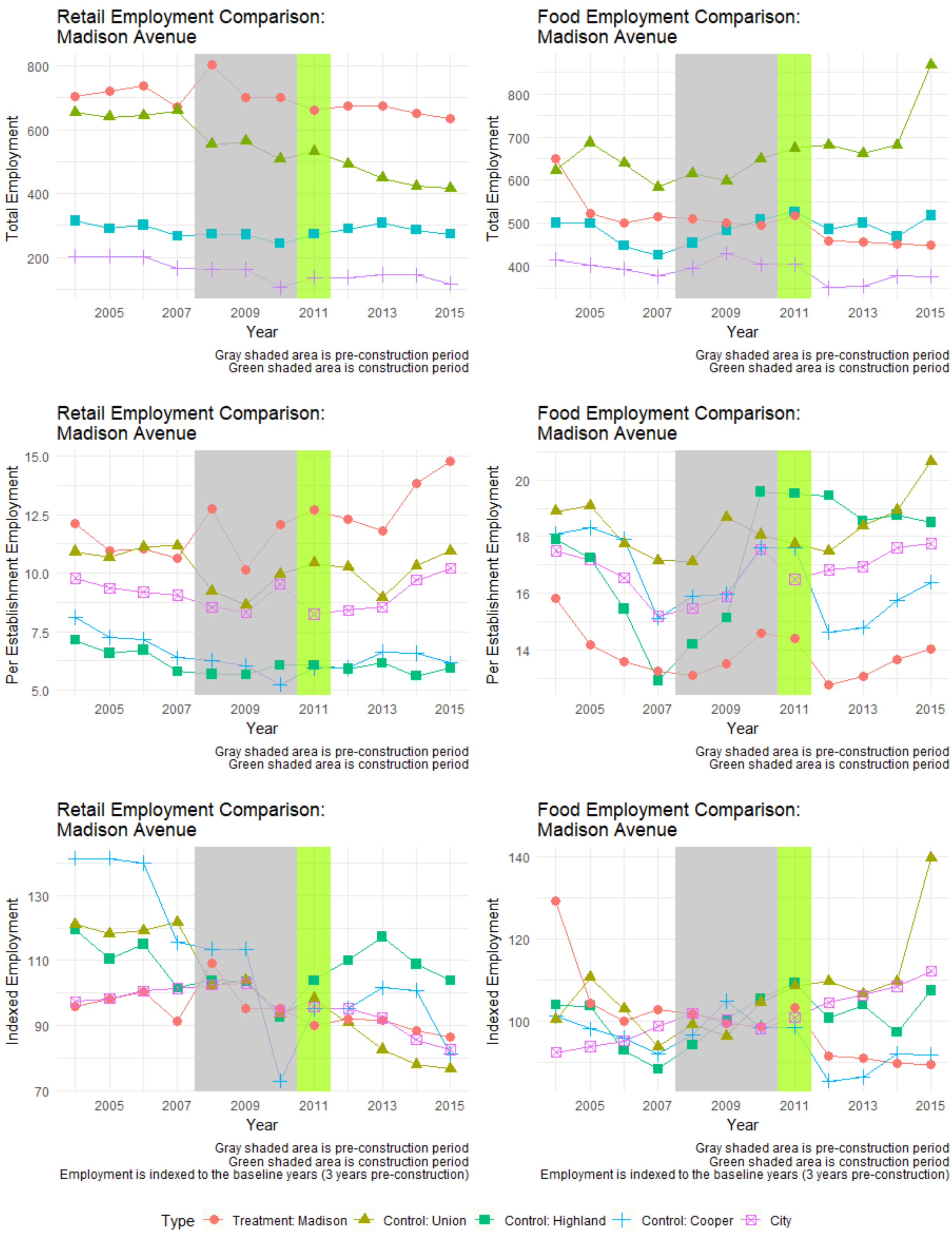


Figure 8-6. Aggregated Employment Trend of Madison Avenue and Control Corridors by NETS Data – Industry Type I

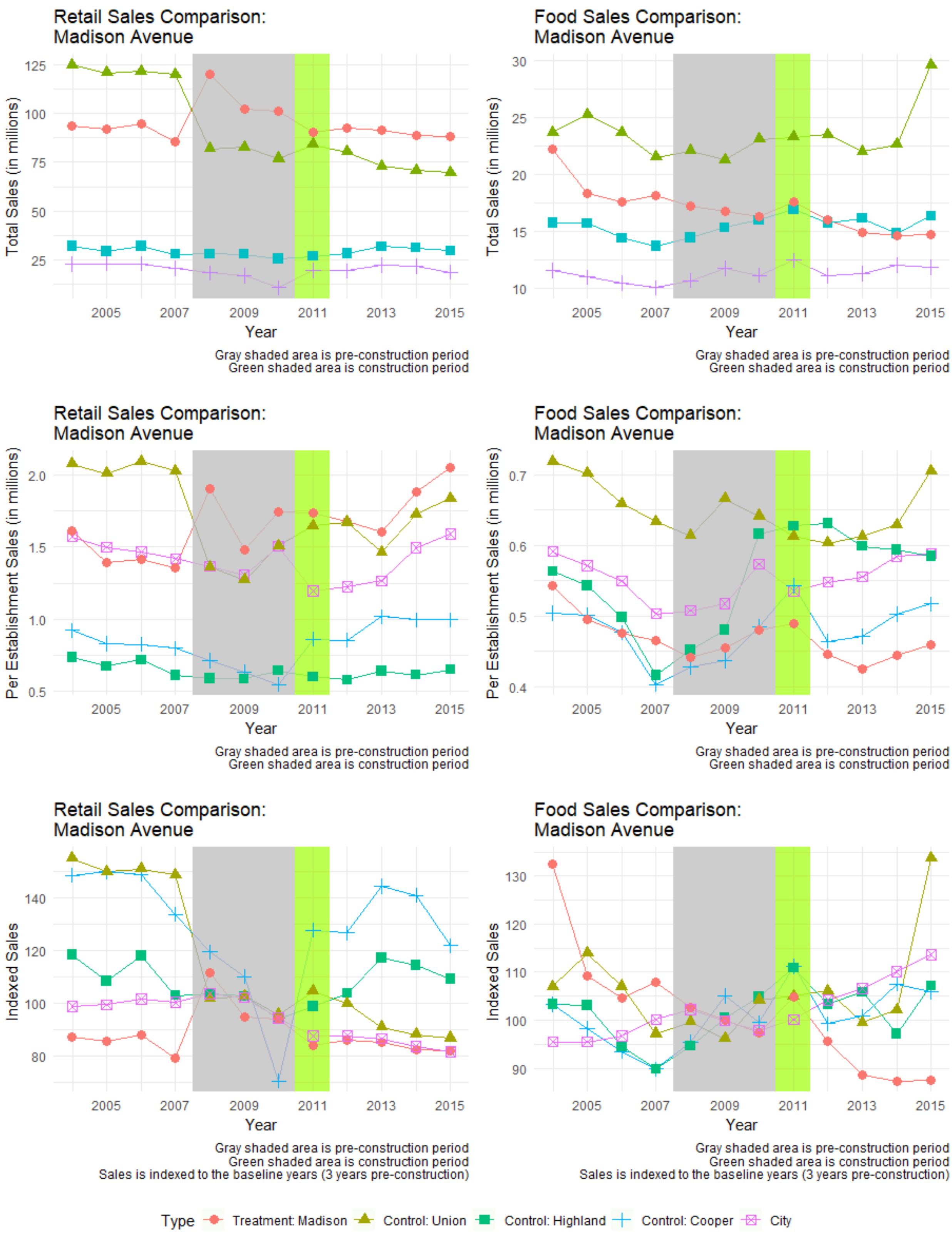


Figure 8-7. Aggregated Sales Trend of Madison Avenue and Control Corridors by NETS Data – Industry Type I

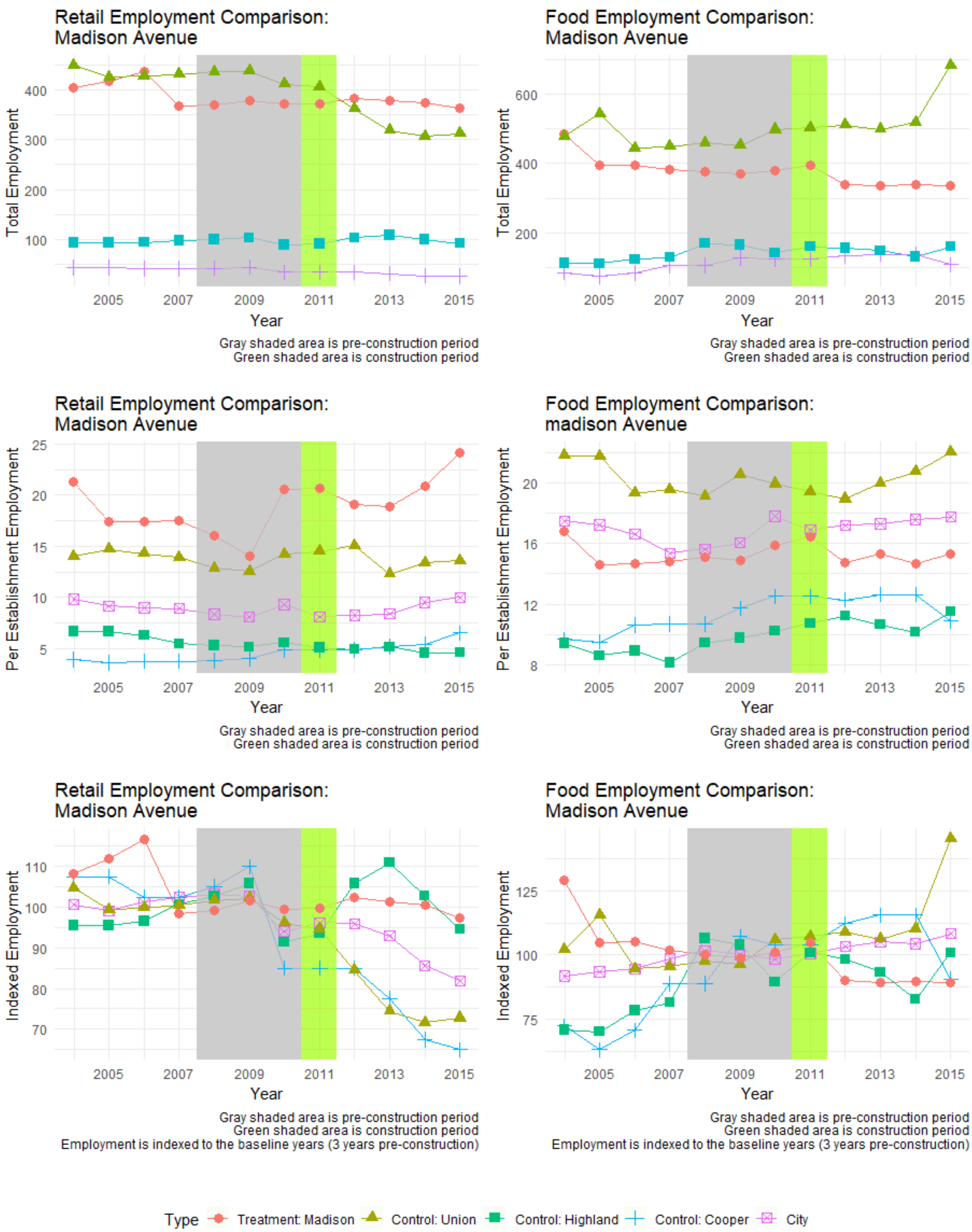


Figure 8-8. Aggregated Employment Trend of Madison Avenue and Control Corridors by NETS Data – Industry Type II

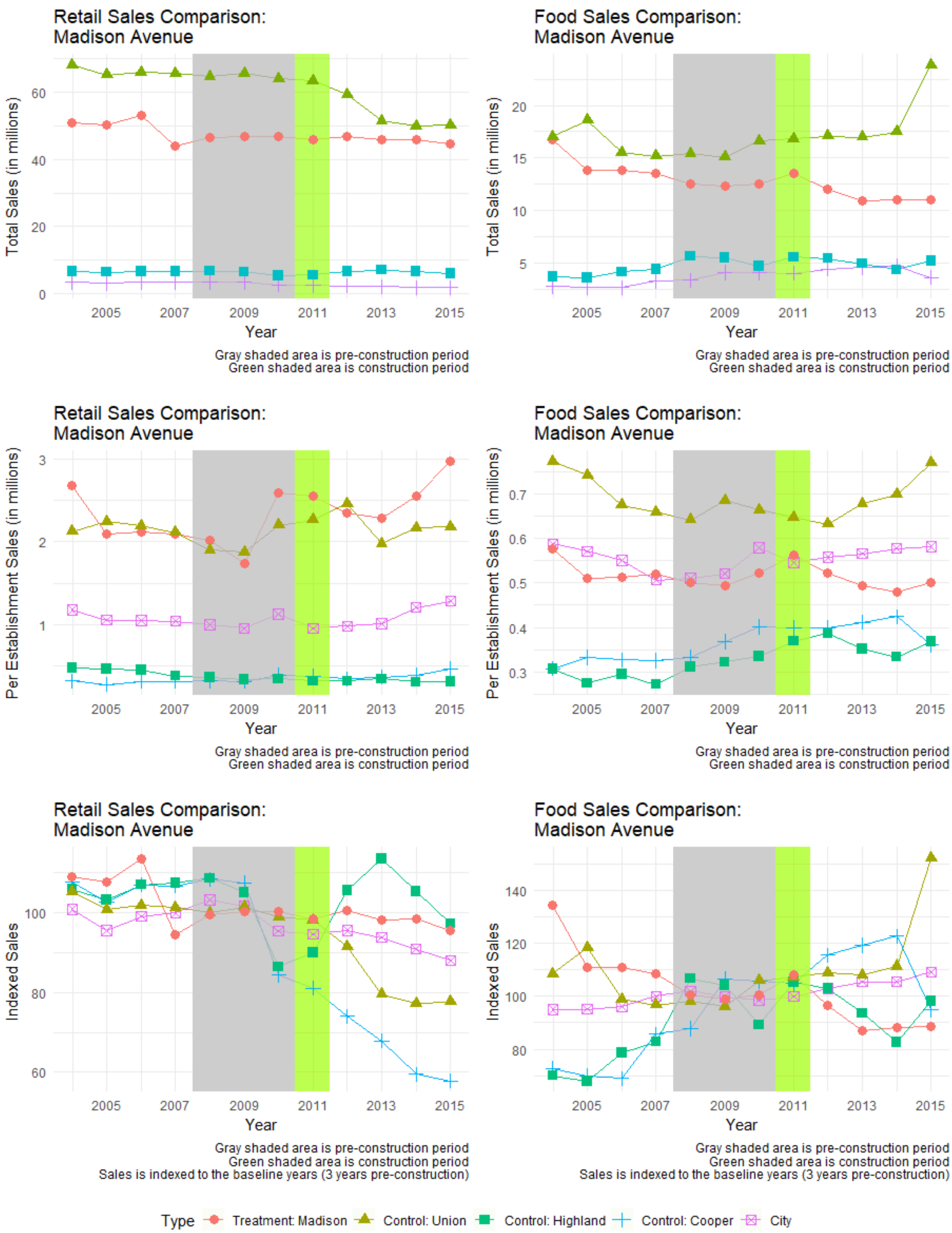


Figure 8-9. Aggregated Sales Trend of Madison Avenue and Control Corridors by NETS Data – Industry Type II

Table 8-14. Madison Corridor Trend Analysis Summary Table (NETS data)

	Retail Baseline		Post-implementation				Food Baseline		Post-implementation			
Area	Base	Growth	1st Year	2nd Year	3rd Year	Average	Base	Growth	1st Year	2nd Year	3rd Year	Average
NETS: (employment, type1)												
Treatment	735	-6.42%	-8.03%	-0.30%	-3.56%	-3.96%	502	-1.48%	-8.37%	-0.65%	-1.31%	-3.44%
Control: Union	541	-4.16%	-9.06%	-8.94%	-5.58%	-7.86%	621	2.89%	9.66%	-2.79%	2.87%	3.25%
Control: Highland	263	-5.51%	9.89%	6.57%	-7.14%	3.11%	482	5.89%	0.83%	3.09%	-6.39%	-0.82%
Control: Cooper	144	-17.79%	-4.86%	6.57%	-0.68%	0.34%	411	1.27%	-14.60%	1.14%	6.48%	-2.33%
NETS: (employment, type2)												
Treatment	108	-7.97%	-14.33%	-0.96%	-3.29%	-6.20%	17	-2.61%	-5.55%	-7.18%	-1.53%	-4.75%
Control: Union	80	-2.96%	0.37%	-8.90%	-3.14%	-3.89%	22	2.44%	7.00%	-6.21%	2.66%	1.15%
Control: Highland	27	-4.67%	4.76%	13.06%	-2.42%	5.14%	15	5.29%	5.23%	2.48%	-8.19%	-0.16%
Control: Cooper	16	-21.92%	22.70%	14.01%	-2.32%	11.46%	11	2.41%	1.33%	1.51%	6.72%	3.19%
NETS: (sales, type1)												
Treatment	373	0.16%	2.41%	-1.05%	-0.79%	0.19%	376	0.41%	-9.84%	-0.88%	0.60%	-3.38%
Control: Union	429	-2.74%	-15.62%	-11.88%	-3.76%	-10.42%	470	4.33%	8.72%	-2.35%	3.81%	3.39%
Control: Highland	97	-5.30%	6.19%	4.85%	-7.41%	1.21%	160	-8.10%	-1.88%	-5.10%	-11.41%	-6.13%
Control: Cooper	40	-8.98%	-15.00%	-8.82%	-12.90%	-12.24%	120	8.73%	12.50%	2.96%	0.00%	5.15%
NETS: (sales, type2)												
Treatment	47	0.29%	-0.16%	-2.33%	0.23%	-0.75%	12	0.09%	0.24%	-9.71%	1.34%	-2.71%
Control: Union	65	-0.51%	-8.98%	-13.18%	-2.87%	-8.34%	16	4.03%	6.70%	-0.68%	3.01%	3.01%
Control: Highland	6	-10.48%	10.30%	7.45%	-7.25%	3.50%	5	-8.35%	8.19%	-9.12%	-11.80%	-4.24%
Control: Cooper	3	-11.12%	-21.17%	-8.23%	-12.37%	-13.92%	4	10.35%	9.71%	3.21%	2.93%	5.28%

1 Baseline is defined as the average of previous three years before construction year;
2 Pre-growth rate is defined as average of baseline annual growth rate;
3 1st year growth rate is defined as the growth rate of the year after construction compared to baseline.

8.1.2.4.2 Difference-in-Difference (DID) Analysis

DID estimations of the NETS dataset are presented below. Since the NETS dataset has longer historical data, we chose to use the data between 2004 and 2015 for our analysis to maintain consistency, and limit this analysis to only the Type II establishments as these are the businesses that directly face the street improvement corridor. In terms of retail employment and sales, there are mixed results depending on the chosen control corridors. While Cooper Street and Highland Street had no significant DID estimator, Union Avenue had a significant negative DID estimator in retail employment and sales. This indicates that the treatment corridor has more active retail levels than Union Avenue. In the case of food service employment and sales, however, all control corridors had significant positive DID estimators, indicating that the bike lane installation had a negative effect on the treatment corridor-level of food service employment and sales. We further investigated the different impacts on retail and food service employment by combining the retail and food service employment together as business employment. The model results show that there are significant positive DID estimators in business employment and sales, except in the case of the Union Avenue control corridor. The DID analyses of the Madison Avenue corridor showed that the street improvement may have had a negative impact on overall business activities.

Table 8-16. Madison Avenue DID Regression Results (NETS, Type I)

Madison Avenue Corridor Difference-in-Difference Estimates (Type I)

	Dependent variable:					
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.	CNS07 Retail Sales	CNS18 Food Sales	business 'Business' Sales
TypeControl: S Cooper St	-545.125***	-123.500***	-84.774***	-77.899***	-6.875***	-668.625***
	(19.1)	(20.4)	(5.3)	(5.2)	(0.7)	(25.4)
TypeControl: S Highland St	-433.500***	-46.000**	-71.330***	-68.597***	-2.733***	-479.500***
	(19.1)	(20.4)	(5.3)	(5.2)	(0.7)	(25.4)
TypeControl: Union Ave	-118.375***	106.625***	9.012*	4.044	4.968***	-11.75
	(19.1)	(20.4)	(5.3)	(5.2)	(0.7)	(25.4)
prepost	-54.000**	-72.875***	-10.187	-7.228	-2.959***	-126.875***
	(23.3)	(25.0)	(6.5)	(6.4)	(0.9)	(31.1)
TypeControl: S Cooper St:prepost	22.625	34.5	11.762	8.367	3.395**	57.125
	(33.0)	(35.4)	(9.1)	(9.0)	(1.3)	(44.0)
TypeControl: S Highland St:prepost	63.750*	85.250**	12.128	8.685	3.444**	149.000***
	(33.0)	(35.4)	(9.1)	(9.0)	(1.3)	(44.0)
TypeControl: Union Ave:prepost	-95.625***	161.875***	-16.312*	-20.738**	4.426***	66.25
	(33.0)	(35.4)	(9.1)	(9.0)	(1.3)	(44.0)
Constant	712.750***	527.125***	115.501***	97.454***	18.047***	1,239.875***
	(13.5)	(14.5)	(3.7)	(3.7)	(0.5)	(18.0)
Observations	48	48	48	48	48	48
R^2	0.974	0.882	0.942	0.933	0.916	0.974
Adjusted R^2	0.97	0.861	0.932	0.921	0.902	0.97
Residual Std. Error (df = 40)	38.109	40.89	10.564	10.411	1.474	50.794
F Statistic (df = 7; 40)	218.185***	42.757***	92.671***	78.947***	62.616***	217.053***
Note:						*p<0.1; p<0.05 ; p<0.01*

Table 8-15. Madison Avenue DID Regression Results (NETS, Type II)

	Dependent variable:					
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.	CNS07 Retail Sales	CNS18 Food Sales	business 'Business' Sales
TypeControl: S Cooper St	-349.375***	-292.750***	-55.106***	-44.833***	-10.272***	-642.125***
	(7.4)	(17.4)	(1.1)	(0.9)	(0.7)	(18.5)
TypeControl: S Highland St	-294.500***	-257.875***	-50.654***	-41.675***	-8.979***	-552.375***
	(7.4)	(17.4)	(1.1)	(0.9)	(0.7)	(18.5)
TypeControl: Union Ave	38.625***	80.625***	19.837***	17.172***	2.664***	119.250***
	(7.4)	(17.4)	(1.1)	(0.9)	(0.7)	(18.5)
prepost	-15.125	-60.625***	-4.602***	-2.228*	-2.374***	-75.750***
	(9.0)	(21.3)	(1.4)	(1.2)	(0.8)	(22.6)
TypeControl: S Cooper St:prepost	4.375	86.000***	4.421**	1.085	3.336***	90.375***
	(12.8)	(30.1)	(2.0)	(1.6)	(1.1)	(32.0)
TypeControl: S Highland St:prepost	20.75	70.375**	5.161**	2.46	2.701**	91.125***
	(12.8)	(30.1)	(2.0)	(1.6)	(1.1)	(32.0)
TypeControl: Union Ave:prepost	-88.125***	134.625***	-5.403***	-10.345***	4.942***	46.5
	(12.8)	(30.1)	(2.0)	(1.6)	(1.1)	(32.0)
Constant	389.625***	397.875***	61.654***	48.048***	13.607***	787.500***
	(5.2)	(12.3)	(0.8)	(0.7)	(0.5)	(13.1)
Observations	48	48	48	48	48	48
R^2	0.993	0.964	0.996	0.995	0.958	0.989
Adjusted R^2	0.992	0.958	0.995	0.995	0.951	0.987
Residual Std. Error (df = 40)	14.775	34.727	2.255	1.881	1.3	36.922
F Statistic (df = 7; 40)	849.956***	153.324***	1,293.897***	1,254.733***	130.858***	524.545***
Note:						*p<0.1; p<0.05 ; p<0.01*

8.1.2.4.3 *Interrupted Time Series (ITS) Analysis*

Similar to DID analysis, we only conducted the ITS analysis on Type II block-face-level establishments using NETS data, and chose to utilize only the data between 2004 and 2015 for this analysis. The models indicate that the street improvement had no significant impact on business employment and sales.

Table 8-17. Madison Avenue ITS Regression Results (NETS, Type I)

Madison Avenue Corridor Interrupted Time Series Estimates (Type II)

	Dependent variable:					
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.	CNS07 Retail Sales	CNS18 Food Sales	business 'Business' Sales
ts_year	-7.464**	-9.440*	-1.224**	-0.812**	-0.412**	-16.905***
	(2.7)	(4.1)	(0.4)	(0.3)	(0.1)	(4.6)
prepost	14.286	-95.757	0.127	1.382	-1.254	-81.471
	(84.8)	(127.5)	(11.6)	(10.1)	(4.6)	(143.7)
ts_year:prepost	1.464	8.74	0.249	0.12	0.129	10.205
	(8.4)	(12.6)	(1.1)	(1.0)	(0.5)	(14.2)
Constant	423.214***	440.357***	67.161***	51.700***	15.461***	863.571***
	(13.8)	(20.8)	(1.9)	(1.7)	(0.7)	(23.4)
Observations	12	12	12	12	12	12
R^2	0.555	0.705	0.727	0.546	0.757	0.792
Adjusted R^2	0.388	0.594	0.624	0.376	0.666	0.714
Residual Std. Error (df = 8)	17.716	26.641	2.415	2.12	0.952	30.029
F Statistic (df = 3; 8)	3.324*	6.362**	7.096**	3.211*	8.298***	10.176***
Note:						*p<0.1; **p<0.05**; p<0.01*

Table 8-18. Madison Avenue ITS Regression Results (NETS, Type II)

Madison Avenue Corridor Interrupted Time Series Estimates (Type I)

	Dependent variable:					
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.	CNS07 Retail Sales	CNS18 Food Sales	business 'Business' Sales
ear	-4.595	-12.631*	0.392	0.935	-0.543**	-17.226**
	(6.2)	(5.7)	(1.5)	(1.5)	(0.2)	(6.8)
post	79.671	-88.764	12.999	13.937	-0.938	-9.093
	(191.6)	(177.1)	(45.4)	(46.5)	(5.7)	(211.9)
ear:prepost	-10.105	8.731	-2.432	-2.55	0.118	-1.374
	(18.9)	(17.5)	(4.5)	(4.6)	(0.6)	(20.9)
stant	733.429***	583.964***	113.736***	93.245***	20.491***	1,317.393***
	(31.2)	(28.8)	(7.4)	(7.6)	(0.9)	(34.5)
servations	12	12	12	12	12	12
	0.432	0.657	0.297	0.2	0.767	0.785
usted R^2	0.219	0.528	0.033	-0.1	0.679	0.704
idual Std. Error (df = 8)	40.03	36.998	9.489	9.716	1.181	44.263
tatistic (df = 3; 8)	2.027	5.099**	1.125	0.668	8.763***	9.718***
e:						*p<0.1; **p<0.05**; p<0.01*

8.1.3 Distributional Analysis

The distributional analysis aims to track the demographic changes of residents along the treatment corridor, control corridors and the city as a whole before and after the bike lane installation to examine any potential equity outcomes of the bike lane installation on the Madison Avenue corridor. This analysis is conducted using the LEHD dataset, where income indicators are available for a longer time period (covering both the pre- and post-construction periods), while gender, race and education indicators are only available starting in 2009.

8.1.3.1 Income

All four corridors experienced drops in employment after 2009, except Cooper Street. There was a small decrease in high-income employment on the treatment corridor, while Union Street experienced the opposite trend. However, as the income variable is not indexed by inflation, the drop in low-income employment may be entirely due to inflationary reasons.

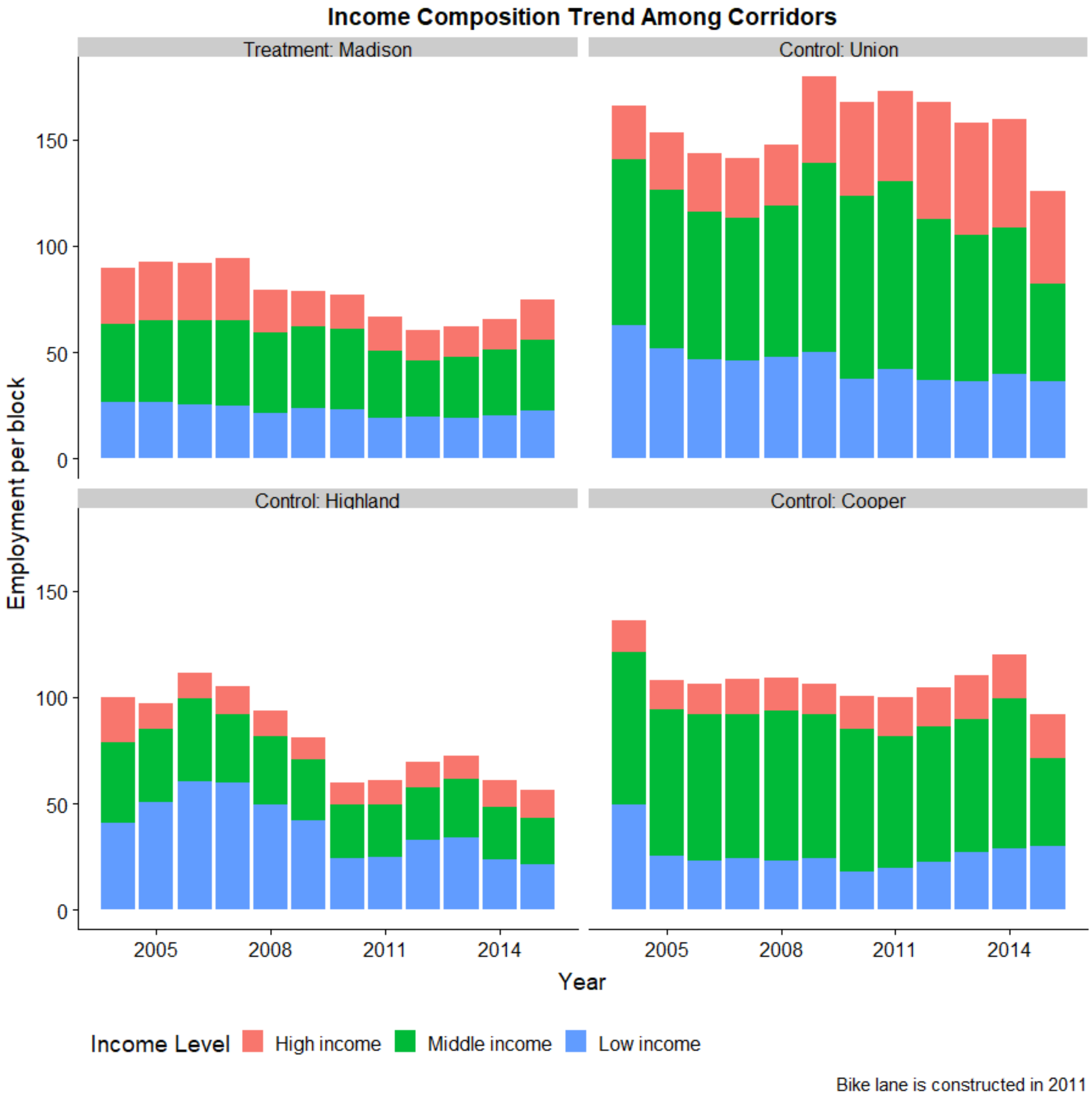


Figure 8-10. Madison Avenue Income Employment Level Composition Trend

8.1.3.2 Race

8.1.3.2.1 Employment

In terms of racial composition of employment along these corridors, the percentage of white employment decreased slightly while the percentage of black employment increased gradually. One exception is Highland Street, where white employment fluctuated and increased slightly and black employment decreased. In general, the trends in the treatment corridor follow the overall city trend in terms of employment racial composition, with small gains in racial diversity over the examined years. We did not observe any divergent pattern in the racial composition of employment along the street improvement corridor when compared with the control corridors or the city.

Due to the fuzzy factor applied in LEHD data, there are some unexpected fluctuations in the annual trends. Table 8-19 summarizes the percentage change of employment racial composition. One thing to note is that, due to the lower number of some groups, the percentage change may look very large even when the actual employment changes are small. The table below shows similar results as the graph, that the racial composition trend on the treatment corridor is similar to the overall city trend and the control corridors.

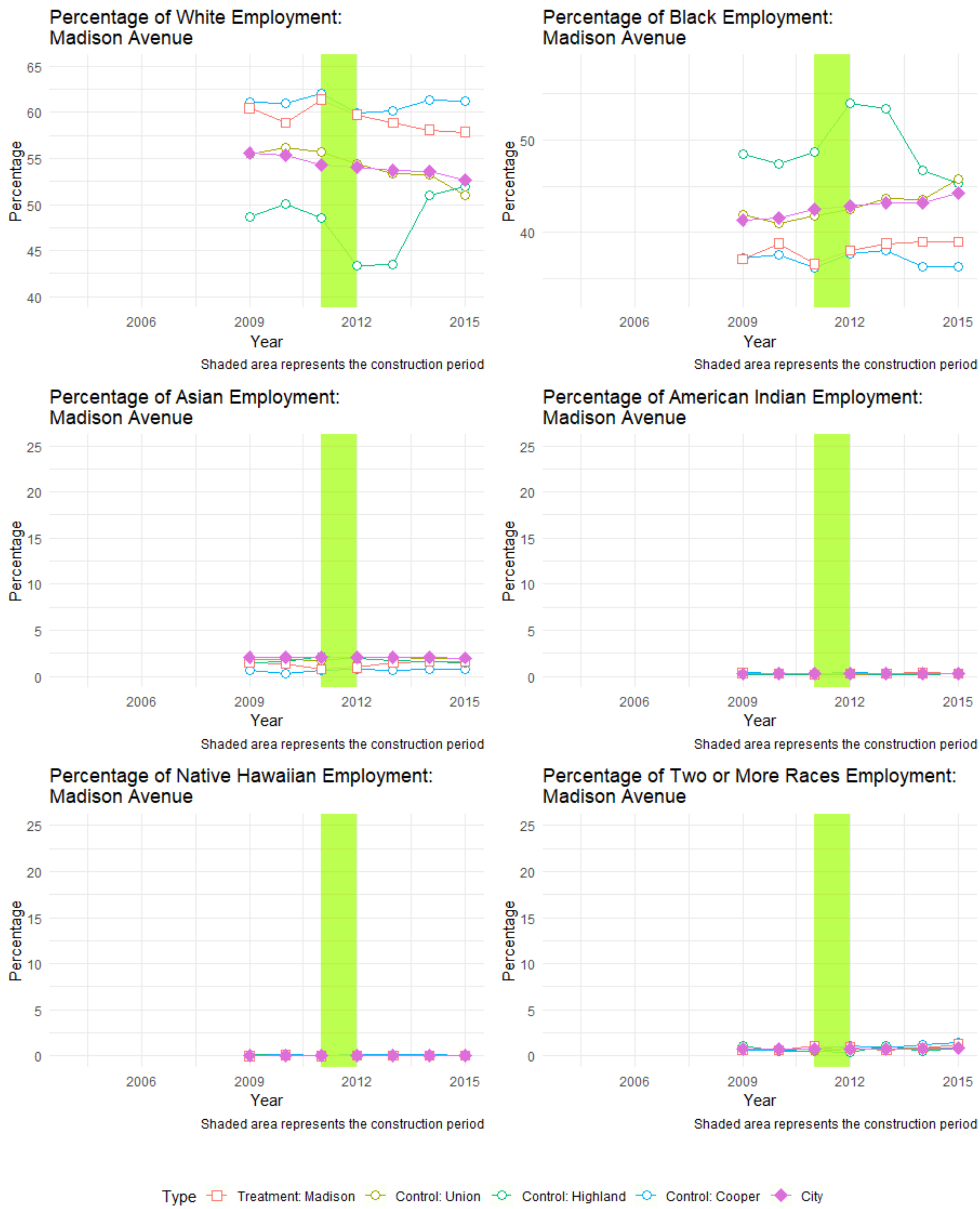


Figure 8-11. Madison Avenue Employment Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 8-19. Madison Avenue Employment Racial Composition Percentage Change (in percentage)

	Treatment: Madison	Control: Cooper	Control: Highland	Control: Union	City
White	-1.04	0.75	6.63	-2.04	-0.85
Black	0.79	-1.23	-5.36	2.63	1.06
American Indian	-0.91	-9.57	-2.47	7.12	1.46
Asian	22.27	-3.76	-6.37	-1.96	-0.69
Hawaiian	-6.32	-33.33	-12.75	0.04	0.73
Two or more races	12.24	11.02	42.12	2.26	2.11

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

8.1.3.2.2 Residents

In terms of residents' racial composition, all of the examined corridors have more white residents and fewer black residents than the city average. However, we did not observe any apparent difference in the trend between the treatment and control corridors.

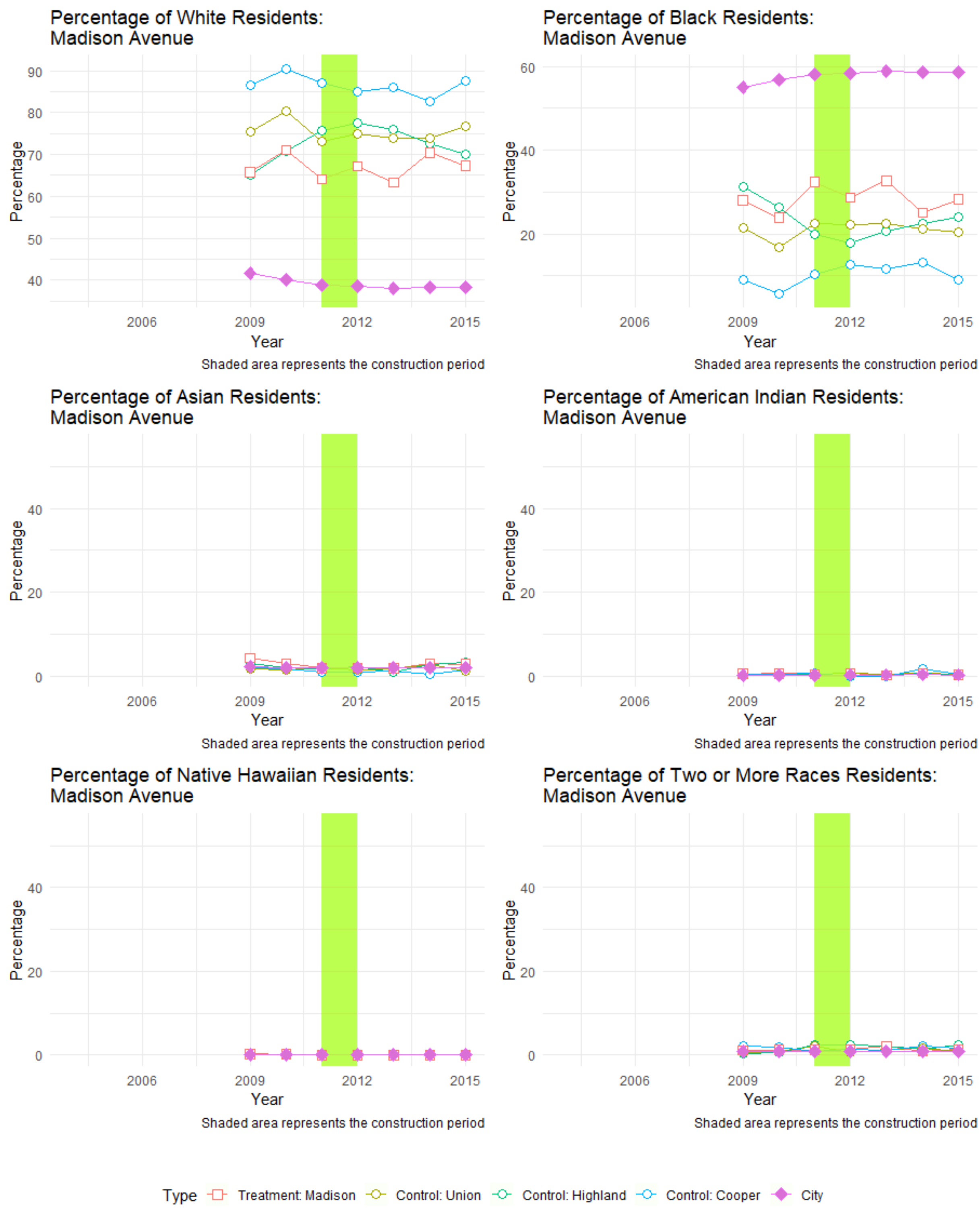


Figure 8-12. Madison Avenue Residents Racial Composition Trend

(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 8-20. Madison Avenue Residents Racial Composition Percentage Change (in percentage)

	Treatment: Madison	Control: Cooper	Control: Highland	Control: Union	City
White	0.04	1.01	-3.23	0.79	-0.11
Black	-0.50	-9.37	11.65	-2.60	0.10
American Indian	-21.91	NA	0.97	-7.72	0.60
Asian	14.36	19.90	17.11	-2.03	-1.72
Hawaiian	NA	NA	NA	-33.33	6.12
Two or more races	-1.07	4.99	0.97	17.88	1.41

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

8.1.3.3 Education

8.1.3.3.1 Employment

In terms of education attainment, most of the selected corridors had fewer college and bachelor's or above employment compared to the city average. The percentage of bachelor's or above level employment decreased while the other three categories all increased slightly on the treatment corridor. However, there is no substantial difference in the trend on the treatment corridor when compared to the control corridors.

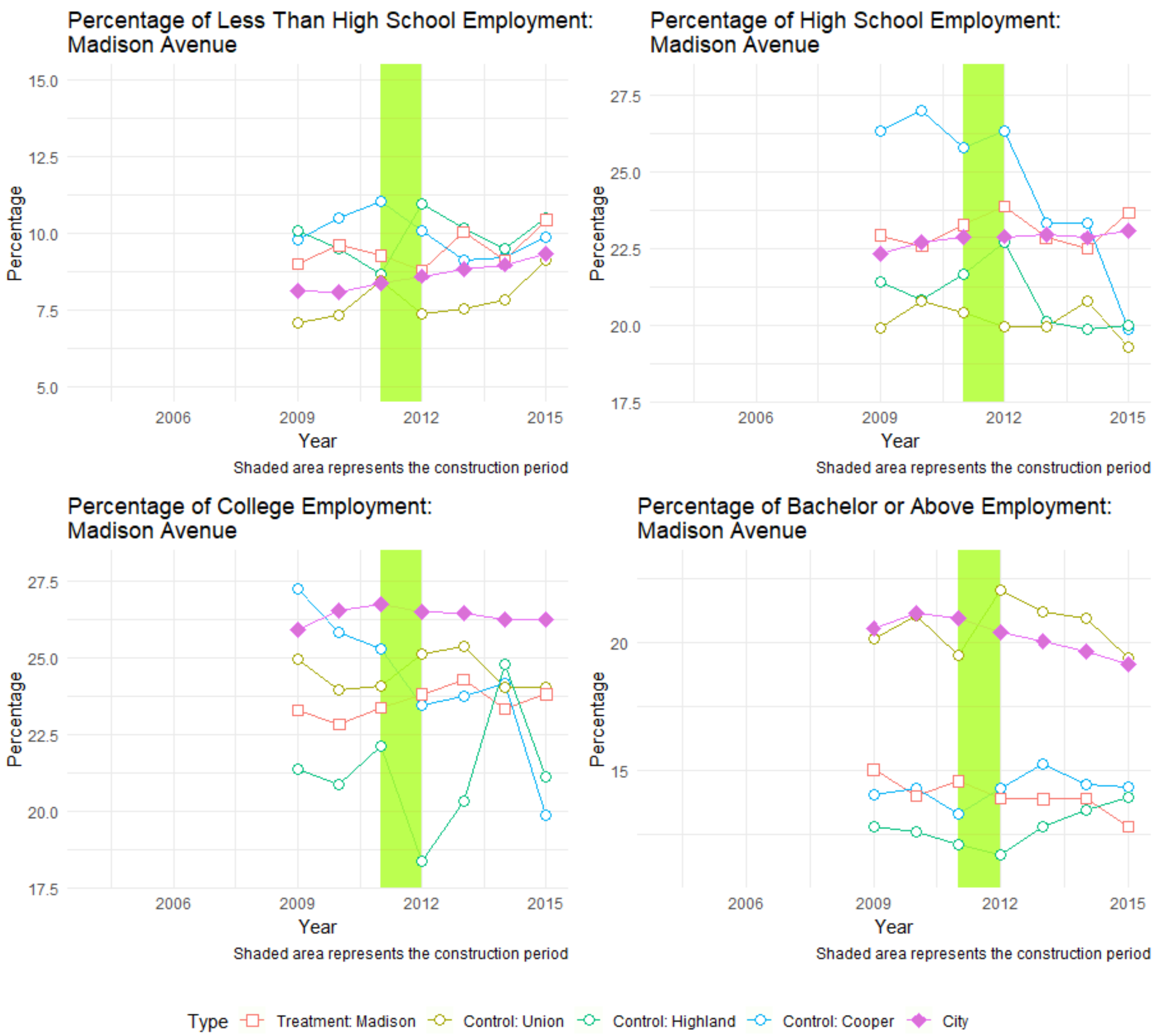


Figure 8-13. Madison Avenue Employment Education Level Composition Trend (Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 8-21. Madison Avenue Employment Education Level Composition Percentage Change (in percentage)

	Treatment: Madison	Control: Cooper	Control: Highland	Control: Union	City
Less than high school	6.03	-0.79	-1.49	8.04	2.82
High school	-0.26	-8.18	-4.01	-1.12	0.27
College	0.01	-5.11	5.03	-1.43	-0.34
Bachelor's or above	-2.66	0.08	6.43	-3.99	-2.04

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

8.1.3.3.2 Residents

In terms of residents' education level, we observe more fluctuation. The selected corridors have more bachelor's or above residents, but fewer lower-education residents compared to the city average, contrary to the employment racial composition trend. Although the resident racial composition trends fluctuated heavily, we again found no substantial differences in trends in the treatment corridor when compared to the control corridors.

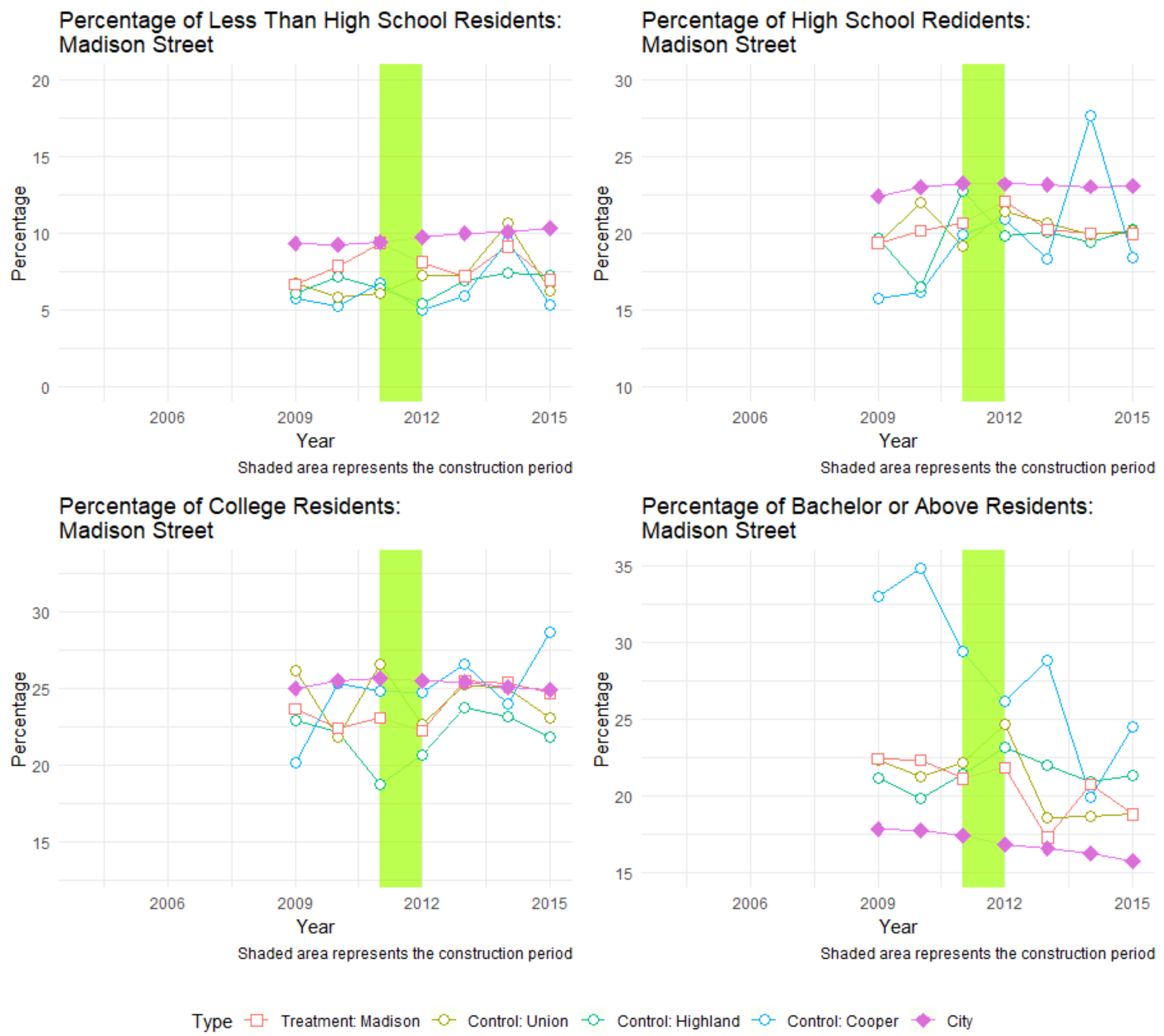


Figure 8-14. Madison Avenue Residents Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 8-22. Madison Avenue Residence Education Level Composition Percentage Change (in percentage)

	Treatment: Madison	Control: Cooper	Control: Highland	Control: Union	City
Less than high school	-4.78	2.36	11.58	-4.45	2.09
High school	-3.21	-4.05	0.74	-2.05	-0.16
College	3.68	5.37	1.82	0.57	-0.78
Bachelor's or above	-2.19	-2.01	-2.65	-7.88	-2.19

Note: These percentage changes are calculated as the average annual percentage change between 2012 and 2015.

8.1.3.4 Gender

In terms of gender, the female percentage in the treatment corridor is generally similar to the city average. Although the percentage of female employment and residents on the control corridors fluctuated up and down, they generally remained at a relatively constant level. We did not find any particular impact of the street improvement on gender composition on the Madison Avenue corridor.

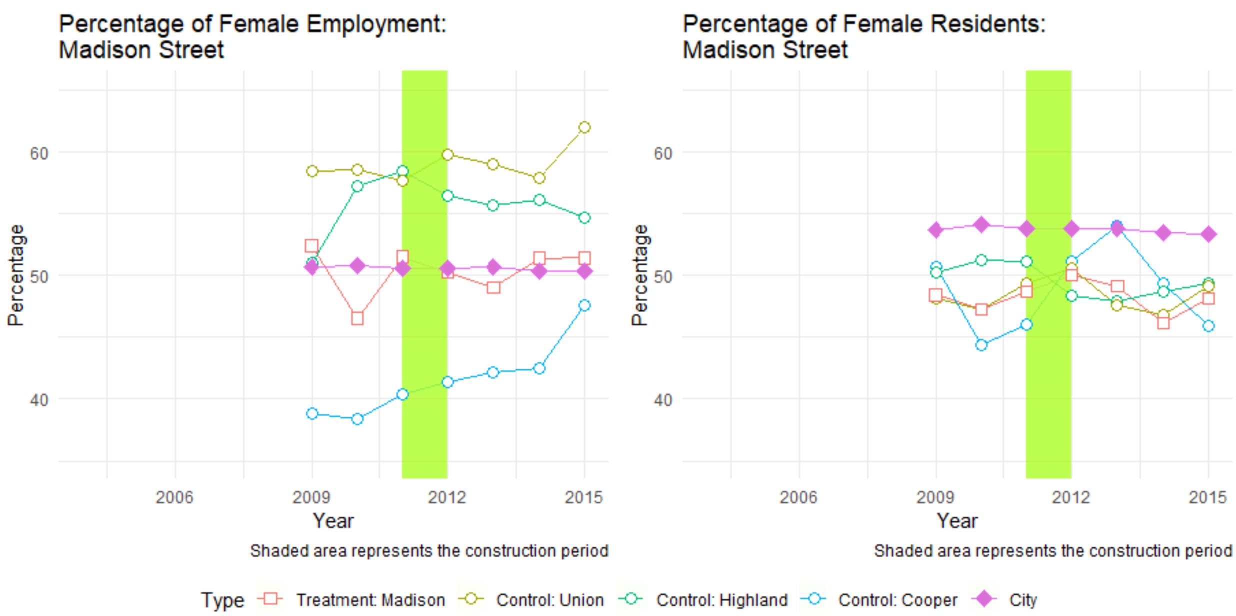


Figure 8-15. Madison Avenue Gender Composition Trend

8.1.4 Madison Avenue Corridor Summary

We used four different data sources, LEHD employment data, retail sales tax data, QCEW data and NETS employment and sales revenue data, to analyze the economic and equity impacts of street improvement on the Madison Avenue corridor. Each of these data sources was analyzed using the aggregated trend analysis, DID estimation and ITS estimation approaches, and we were able to conclude that:

- The LEHD and QCEW employment data on Madison Avenue both show similar trends with its control corridors after the street improvement. Cooper Street experienced a larger bump in employment in the post-construction period, but we suspect that this may be due to events unrelated to the construction of the buffered bike lane on Madison Avenue.
- Analysis of sales tax receipts also shows that sales along Madison Avenue follow a parallel trend when compared with its control corridors, with no detrimental impacts to either retail or food services sales after the street improvement.
- DID analyses indicate non-significant or mixed impacts of the Madison Avenue street improvement on the employment and sales economic indicators. However, our ITS analyses show positive and statistically significant impacts of the street improvement on both food employment and retail sales on Madison Avenue, suggesting a positive causal relationship.
- The environment justice indicators generally followed a similar trend on the treatment corridor, control corridors and the city. We do not observe any significant divergent patterns in demographic trends along the street improvement corridor when compared with the control corridors or the city.

8.2 BROAD AVENUE

A buffered bike lane (separated by parking) was installed on Broad Avenue in 2010. However, it is a relatively short improvement project, involving only five blocks along the corridor. The control corridors are Cooper Street and Central Avenue. The two control corridors are not located away from the treatment corridor, and have higher traffic volumes than that of the treatment corridor.

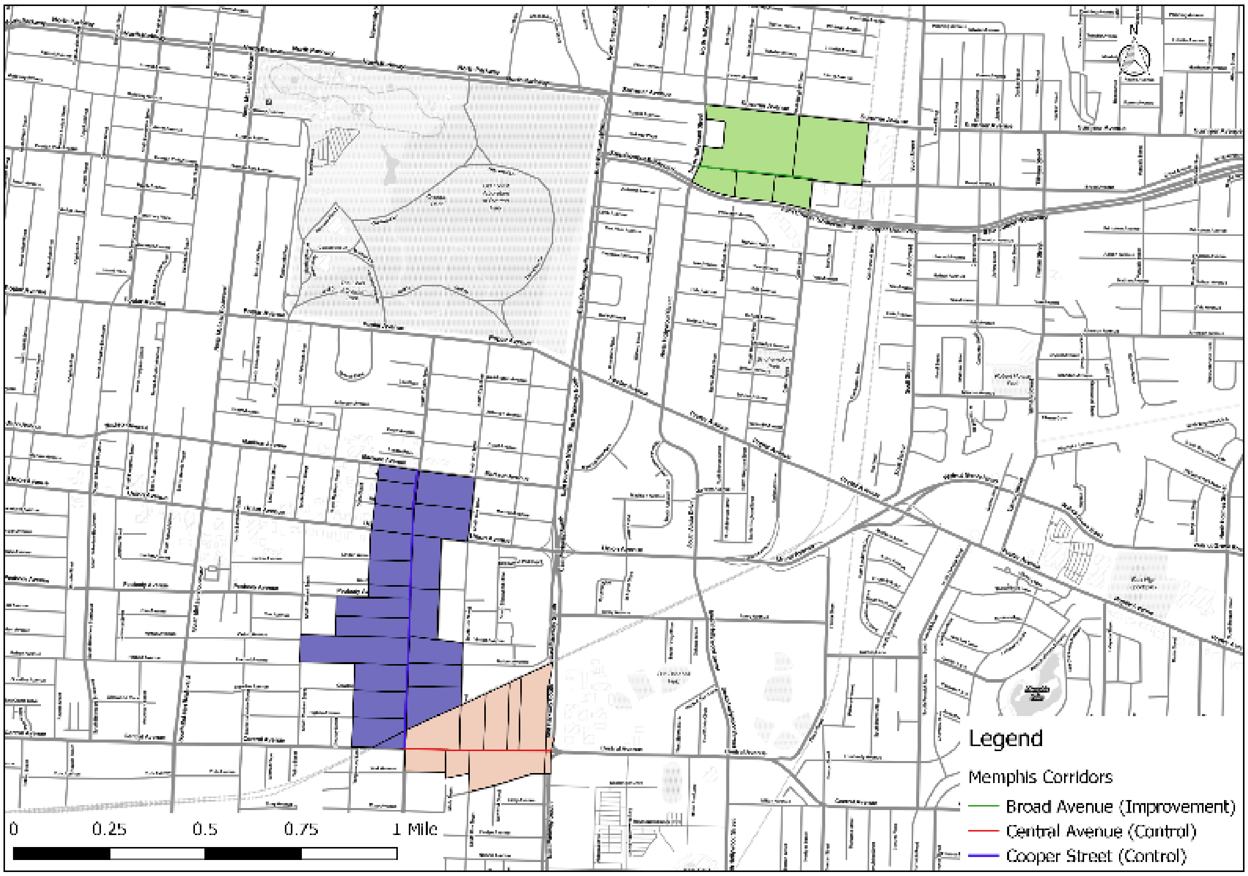


Figure 8-16. Memphis Broad Avenue Corridor Map

8.2.1 Corridor Selection

The following table shows total, retail, and food employment for Broad Avenue, Central Avenue, and Cooper Street as well as the city-based percentile ranks of employment on the corridors. Although the Cooper Street corridor has much more total employment than the others, they share similar amounts of street-level retail and food employment, which is also shown in the percentile ranks of employment per block.

Table 8-23. Comparison of Business Jobs Per Block Percentiles Among Broad Corridors

	Tot Emp.	Retail Emp.	Food Emp.	Tot (%)	Retail (%)	Food (%)
Broad Ave.	40	13	4	50-60	75-80	65-70
Central Ave.	53	6	5	60-65	65-70	70-75
Cooper St.	124	6	12	75-80	65-70	75-80

We also performed a series of t-tests in order to determine whether the average employment levels per block between the treatment and control corridors are statistically significantly different. A statistically significant result here would suggest that the corridors are not necessarily comparable. In terms of absolute employment levels, both control corridors show non-significant t-test results, indicating that they have similar employment levels as the treatment corridor. However, we performed a second set of t-tests on the business/service employment ratios between the corridors. Both corridors show significant results to some extent, suggesting that they have a different structure of business versus service jobs from treatment corridor. It is clear that the two control corridors have more service-related jobs other than business employment.

The following table shows a summary of the corridor comparison analysis for all treatment and control corridor groups, with nine comparability indicators for each group. With respect to the Broad Avenue corridor, we find both Cooper Street and Central Avenue to be equally comparable to the treatment corridor. While there are some differences between the control corridors and the Broad Avenue corridor, we were unable to identify other potential control corridors that may be more suitable for analysis.

Treatment Corridor	**Indicator**		**Broad Avenue**	
Control Corridor			**Cooper**	**Central**
Transportation/ Geography	Geographic Proximity		x	x
	Street Classification		✓	✓
	Role in Street Network		✓	✓
Business Activity	Job Density Percentile	Retail	✓	✓
		Food	✓	✓
	Share of Business Jobs		x	x
	Employment Growth Rate	Retail	✓	✓
		food	x	✓

Table 8-24. Corridor Comparison Summary

8.2.2 Economic Outcome Analysis

8.2.2.1 LEHD Data

8.2.2.1.1 Aggregated Trend Analysis

On Broad Avenue, we can clearly observe negatively trending retail employment growth subsequent to the street improvement compared to the corresponding control corridors and city-wide trends. Employment in the food service industry, however, shows an opposite trend; the treatment corridor experienced significant continuous growth after the street improvement. While there are some similarities between food service employment on Broad Avenue and the Cooper Street control corridor, the improved corridor outperforms the Central control corridor as well as the city-wide trend. Our aggregated trend analysis of LEHD data shows that the street improvement on Broad Avenue has a negative impact on retail employment, but a strong positive impact on food employment.

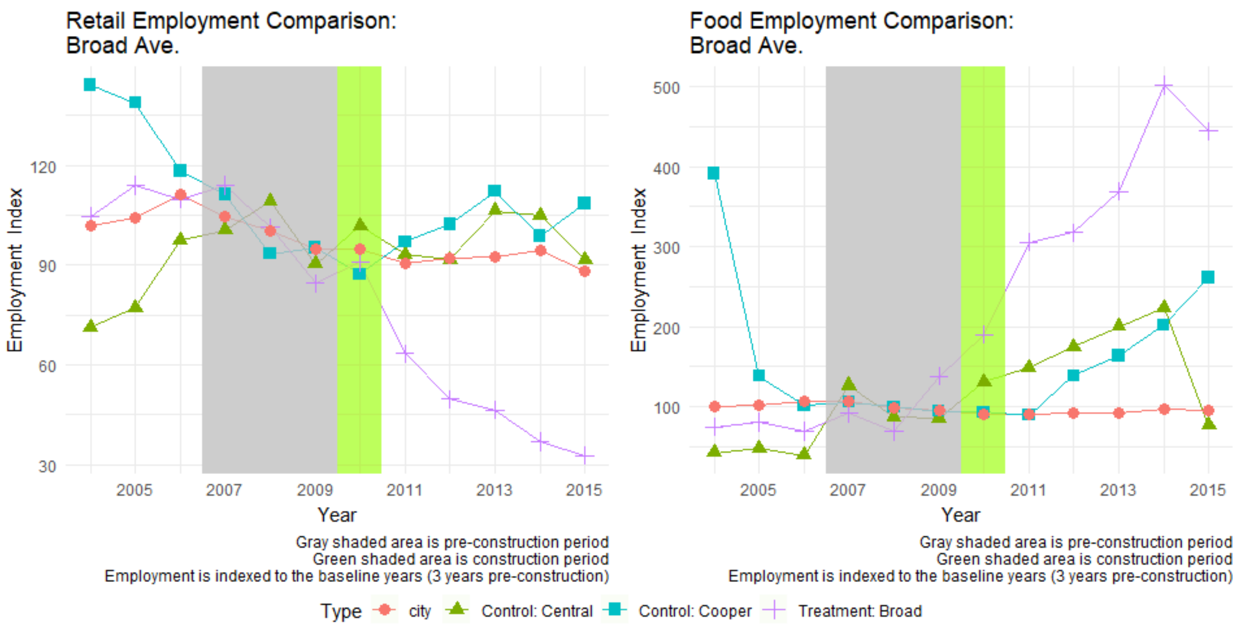


Figure 8-17. Broad Avenue Employment Comparison (LEHD Data)

Table 8-25. Broad Avenue Trend Analysis Summary Table (LEHD Data)

Area	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
LEHD: [employment]												
Treatment	95	-13.89%	-36.84%	-21.67%	-6.38%	-21.63%	17	37.50%	211.76%	3.77%	16.36%	77.30%
Control: Cooper	112	-7.05%	-2.68%	5.50%	9.57%	4.13%	235	-5.58%	-10.21%	54.50%	18.10%	20.80%
Control: Central	69	-4.32%	-7.25%	-1.56%	15.87%	2.35%	64	-16.32%	48.44%	17.89%	14.29%	26.87%

1 Baseline is defined as the average of the three years prior to the construction year;
2 Pre-growth rate is defined as the average of the baseline annual growth rates;
3 Post-growth rate is defined as the average annual growth rate of three time points after the construction year.

8.2.2.1.2 Difference-in-Difference (DID) Analysis

DID analysis of LEHD data indicates that the Broad Avenue treatment corridor exhibits a statistically significant and negative effect of the infrastructure construction on retail employment. The effects on other industry sectors, however, are not statistically significant, indicating no specific impact pattern for food industry employment.

8.2.2.1.3 Interrupted Time Series (ITS) Analysis

In the case of the ITS analysis of the Broad Avenue corridor using LEHD data, only the food industry employment model shows statistically significant results. It indicates that the bike lane installation on Broad Avenue causes greater slope change (or growth) for food service employment, increasing by five more jobs annually than the pre-installation period after the improvement. However, we do not find significant effects on retail employment.

Table 8-26. Broad Avenue DID Regression Results (LEHD Data)

Broad Ave. Corridor Difference-in-Difference Estimates

	Dependent variable:	
	CNS07 Retail Emp.	CNS18 Food Emp.
TypeControl: Central	-33.714***	33.571
	(7.496)	(68.863)
TypeControl: Cooper	29.286***	326.286***
	(7.496)	(68.863)
prepost	-53.886***	49.486
	(8.211)	(75.435)
DID estimator: Central	57.314***	4.629
	(11.612)	(106.682)
DID estimator: Cooper	43.914***	8.914
	(11.612)	(106.682)
Constant	97.286***	17.714
	(5.3)	(48.693)
Observations	36	36
R^2	0.842	0.62
Adjusted R^2	0.816	0.557
Residual Std. Error (df = 30)	14.023	128.83
F Statistic (df = 5; 30)	31.960***	9.799***
Note:		*p<0.1;* ***p<0.05;*** p<0.01

Table 8-27. Broad Avenue ITS Regression Results (LEHD Data)

Broad Ave. Corridor Interrupted Time Series Estimates

	Dependent variable:	
	CNS07 Retail Emp.	CNS18 Food Emp.
Yearly trend	-3.679**	2.857*
	(1.25)	(1.264)
Level change	1.4	-19.086
	(21.844)	(22.09)
Slope change	-3.321	5.143*
	(2.436)	(2.463)
Constant	112.000***	6.286
	(5.588)	(5.651)
Observations	12	12
R^2	0.964	0.957
Adjusted R^2	0.95	0.941
Residual Std. Error (df = 8)	6.612	6.686
F Statistic (df = 3; 8)	71.200***	59.730***
Note:		*p<0.1; p<0.05;* p<0.01

8.2.2.2 Sales Tax Data

8.2.2.2.1 Aggregated Trend Analysis

As mentioned previously, sales taxes can be a more sensitive measure of economic activity than employment and the data is typically available on a more frequent basis. Despite this advantage, we only have retail sales data, so we are unable to use this more sensitive measure to identify impacts on the food service industry. Retail sales receipts on Broad Avenue maintain a consistently lower level than the Central Avenue and Cooper Street control corridors in absolute terms over time. The rate of change in growth, however, in retail receipts on Broad Avenue accelerated post-construction, performing significantly better than the control corridors. Thus, we can conclude that the bike lane installation on Broad Avenue results in a substantial increase in retail gross sales.

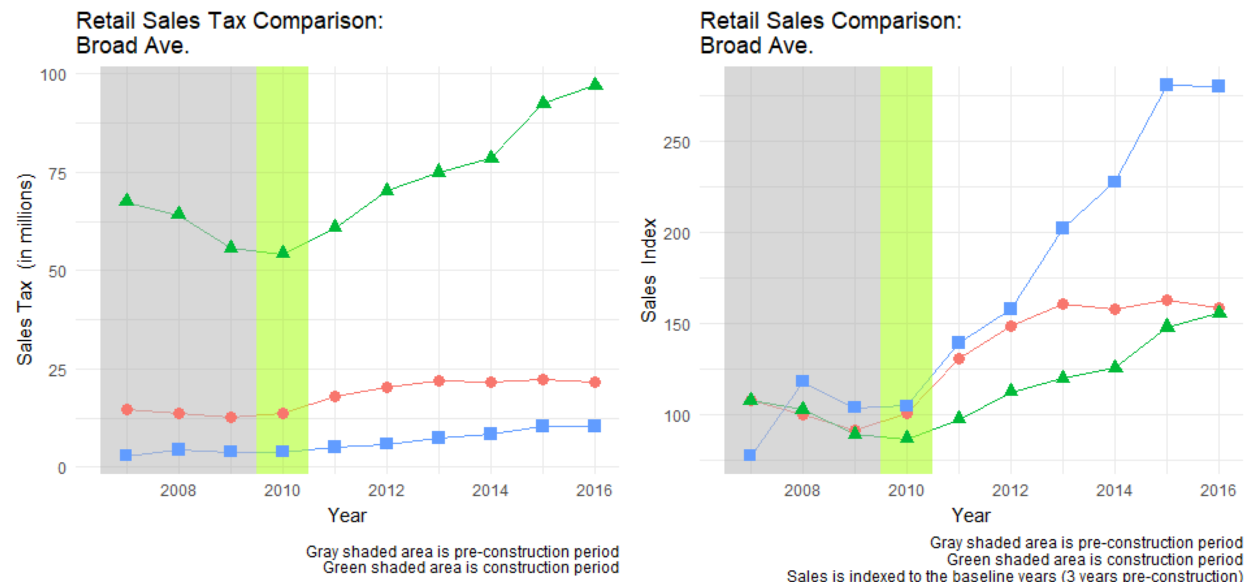


Figure 8-18. Broad Avenue Sales Revenue Comparison (Sales Data)

Table 8-28. Broad Avenue Trend Analysis Summary Table (Sales Data)

	Retail						**Food**			
	Baseline		**Post-implementation**				**Baseline**		**Post-implementatic**	
	Bas e	**Growth**	**1st Year**	**2nd Year**	**3rd Year**	**Avg.**	**Base**	**Growth**	**1st Year**	**2nd Year**
Sales: [sales revenue, 1,000,000$]										
	3.7	20.19%	39.39%	13.39%	27.98%	26.92%	-	-	-	-
	62.5	-8.94%	-2.52%	15.35%	6.83%	6.55%	-	-	-	-
	13.7	-8.00%	30.51%	14.07%	8.06%	17.55%	-	-	-	-

1 Baseline is defined as the average of the three years prior to the construction year;
2 Pre-growth rate is defined as the average of the baseline annual growth rates;
3 Post-growth rate is defined as the average annual growth rate of three time points after the construction year.

8.2.2.2.2 Difference-in-Difference (DID) Analysis

Due to the absolute value differences in sales tax volumes between the treatment corridor and control corridors, especially Cooper Street, the model results indicate a negative impact of the bike lane installation on Broad Avenue. However, we believe that these results should be interpreted with caution, as the control corridors in this circumstance started out with much higher sales tax receipts and may be less comparable than we would like. When we examined the number of establishments, we found that the Broad Avenue street improvement had a positive impact on the number of establishments compared to the Central Avenue control corridor.

Table 8-29. Broad Avenue DID Regression Results (Sales Data)

Broad Ave. Corridor Difference-in Difference Estimates		
	Dependent variable:	
	gross_sales	business
TypeControl: Central	10,012,101**	15.655***
	(4,785,404)	(2.214)
TypeControl: Cooper	56,674,377***	29.947***
	(4,785,404)	(2.214)
prepost	4,171,963	7.922***
	(4,368,456)	(2.022)
DID estimator: Central	3,094,667	-6.915**
	(6,177,930)	(2.859)
DID estimator: Cooper	14,484,859**	-2.415
	(6,177,930)	(2.859)
Constant	3,724,262	6.324***
	(3,383,792)	(1.566)
Observations	30	30
R^2	0.958	0.949
Adjusted R^2	0.95	0.938
Residual Std. Error (df = 24)	6,767,583	3.132
F Statistic (df = 5; 24)	110.284***	88.431***
Note:		*p<0.1; **p<0.05;*** p<0.01

8.2.2.2.3 Interrupted Time Series (ITS) Analysis

ITS analyses of the retail sales and number of establishments from the sales tax data indicate negative level changes and positive slope changes after the buffered bike lane was installed on Broad Avenue. Although we need extra time points to verify the retail sales impacts in the future, the higher growth rates are indicative that the retail sales are growing more rapidly than before.

Table 8-30. Broad Avenue ITS Regression Results (Sales Data)

Broad Ave. Corridor Time Series Estimates		
	Dependent variable:	
	gross_sales	business
Yearly trend	248,699.6	0.523
	(241,748.2)	(0.5)
Level change	-3,842,012**	-8.678**
	(1,194,265)	(2.468)
Slope change	902,730.3**	1.865**
	(274,116.7)	(0.566)
Constant	3,102,513***	5.016**
	(662,054.8)	(1.368)
Observations	10	10
R^2	0.974	0.971
Adjusted R^2	0.961	0.957
Residual Std. Error (df = 6)	540,565.5	1.117
F Statistic (df = 3; 6)	74.470***	67.249***
Note:		*p<0.1; **p<0.05;*** p<0.01

8.2.2.3 QCEW Data

8.2.2.3.1 Aggregated Trend Analysis

As mentioned earlier, the QCEW data provided by the state includes establishment counts and total wage information for the retail industry on the corridors. While we do not have access to fully disaggregated data, the increased sample size and detail on establishments and wages is still valuable and expands our understanding of the economic and business dynamics of our corridors.

The Broad Avenue aggregated trend analysis of the QCEW data shows that there were large jumps in both retail and food service activity on the corridors following the construction. Despite a large decline in the following year, the resulting levels of employment continue to be higher than before construction. The employment trends on the control corridors, however, are also similar to those of Broad Avenue. In other words, the aggregated trend analysis here does not provide definitive results of the street improvement on Broad Avenue, and we proceed with further econometric analysis using DID or ITS analysis to identify the impacts on employment activity.

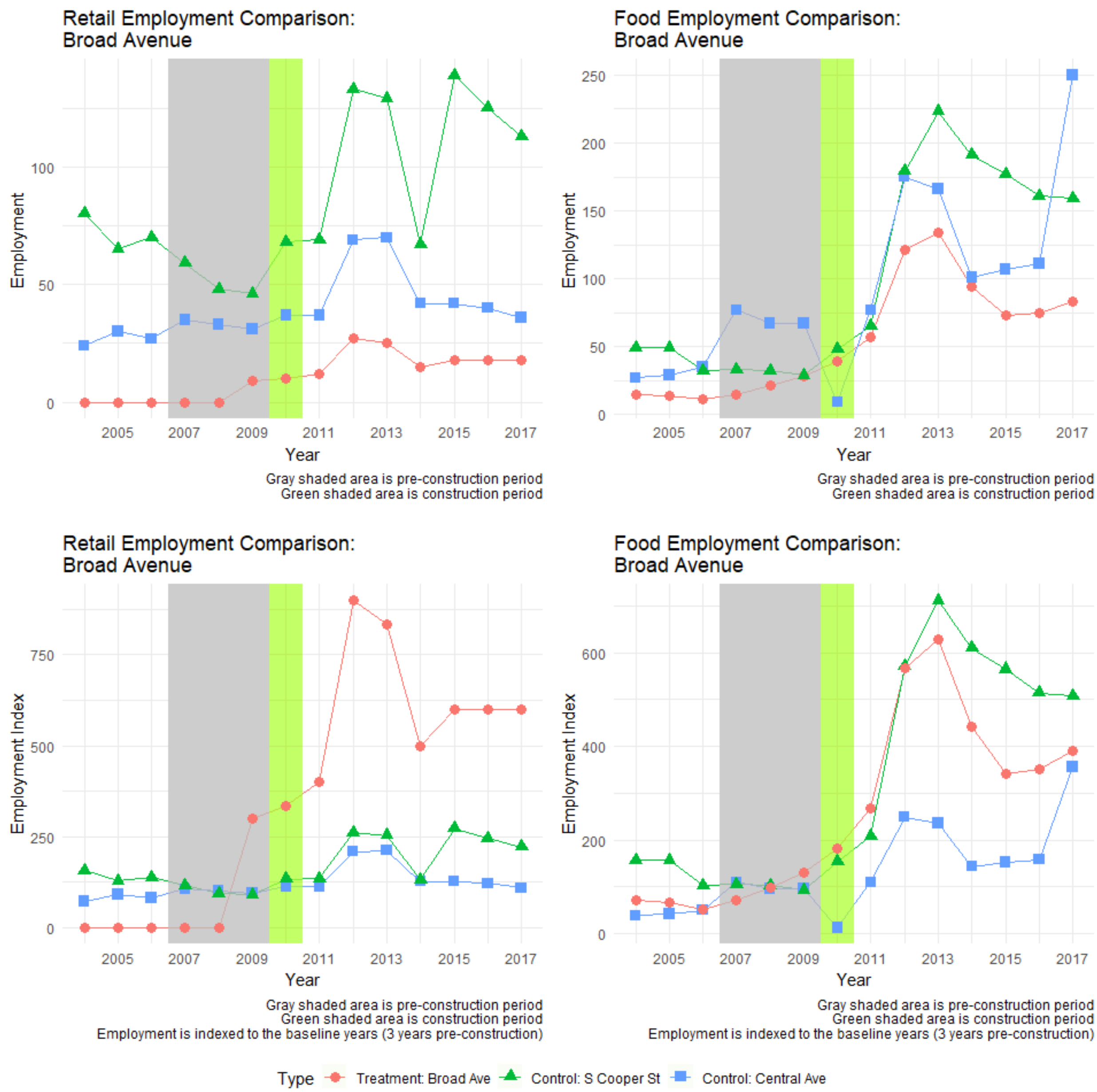


Figure 8-19. Broad Avenue Employment Comparison (QCEW)

Table 8-31. Broad Avenue Trend Analysis Summary Table (QCEW)

	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
Area	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
QCEW: [employment]												
Treatment	3	-	300.00%	125.00%	-7.41%	139.20%	21	36.67%	171.43%	112.28%	10.74%	98.15%
Control: Cooper	51	-11.41%	35.29%	92.75%	-3.01%	41.68%	31	-6.20%	109.68%	175.38%	24.58%	103.21%
Control: Central	33	-5.89%	12.12%	86.49%	1.45%	33.35%	70	-6.49%	10.00%	127.27%	-5.14%	44.04%

1 Baseline is defined as the average of the three years prior to the construction year;
2 Pre-growth rate is defined as the average of the baseline annual growth rates;
3 Post-growth rate is defined as the average annual growth rate of three time points after the construction year.

In the case of wages, the aggregated trend analysis indicates that the growth rates in wages in both the retail and food sectors on the Broad Avenue treatment corridor increased after the street improvement. In particular, there was a large increase in wage growth on Broad Avenue after construction. Nonetheless, comparing the wage change trends of the Cooper Street and Central Avenue corridors, it is unclear whether the street improvement had any discernable impact on retail and food wage growth. Additional analyses are needed to clarify the impacts of the street improvement on economic activities.

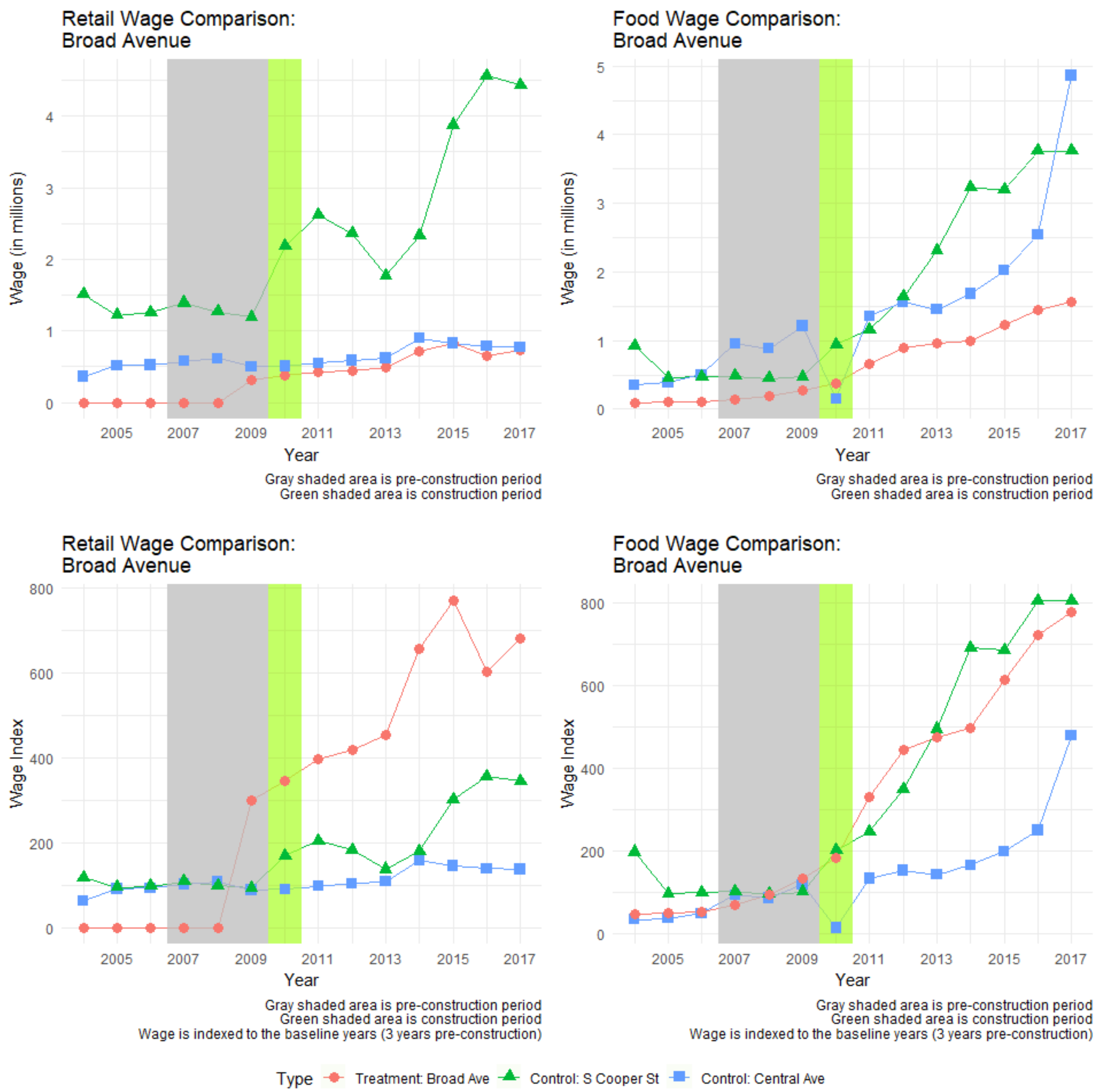


Figure 8-20. Broad Avenue Wage Comparison (QCEW)

8.2.2.3.2 *Difference-in-Difference (DID) Analysis*

DID analysis of QCEW data indicates a statistically significant and negative effect of the infrastructure construction on the number of employment and wages on Broad Avenue when using Cooper Street as a control group. However, when we employed Central Avenue as the control corridor, the differences are not statistically significant.

Table 8-32. Broad Avenue DID Regression Results (QCEW Data)

Broad Ave. Corridor Difference-in-Difference Estimates (Employment)

	Dependent variable:		
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.
TypeControl: Central Ave	28.286*** (8.033)	24 (18.998)	52.286** (23.39)
TypeControl: S Cooper St	59.571*** (8.033)	18.429 (18.998)	78.000*** (23.39)
prepost	16.286* (8.033)	70.571*** (18.998)	86.857*** (23.39)
TypeControl: Central Ave:prepost	0.714 (11.36)	26 (26.867)	26.714 (33.078)
TypeControl: S Cooper St:prepost	32.143*** (11.36)	55.571** (26.867)	87.714** (33.078)
Constant	2.714 (5.68)	20.429 (13.434)	23.143 (16.539)
Observations	42	42	42
R^2	0.862	0.729	0.804
Adjusted R^2	0.843	0.692	0.777
Residual Std. Error (df = 36)	15.028	35.542	43.758
F Statistic (df = 5; 36)	45.154***	19.397***	29.494***
Note:			*p<0.1; **p<0.05;*** p<0.01

Broad Ave. Corridor Difference-in-Difference Estimates (Wage)

	Dependent variable:		
	CNS07 Retail Wage	CNS18 Food Wage	business 'Business' Wage
TypeControl: Central Ave	416,048.9 -265,345.40	452,342.4 -372,838.50	868,391.3 -554,005.10
TypeControl: S Cooper St	1,331,515*** -265,345.40	417,505.9 -372,838.50	1,749,021*** -554,005.10
prepost	513,212.4* -265,345.4	923,699** -372,838.50	1,436,911** -554,005.10
TypeControl: Central Ave:prepost	-308,656.1 -375,255	654,395.1 -527,273.20	345,739 -783,481.60
TypeControl: S Cooper St:prepost	1,191,443*** -375,255	1,200,210** -527,273.20	2,391,653*** -783,481.60
Constant	99,559.43 -187,627.50	181,588 -263,636.60	281,147.4 -391,740.80
Observations	42	42	42
R^2	0.825	0.669	0.774
Adjusted R^2	0.801	0.623	0.742
Residual Std. Error (df = 36)	496,415.7	697,516.9	1,036,449
F Statistic (df = 5; 36)	33.954***	14.562***	24.593***
Note:			*p<0.1; **p<0.05;*** p<0.01

8.2.2.3.3 Interrupted Time Series (ITS) Analysis

Using ITS analysis on the QCEW retail employment data shows that the Broad Avenue corridor exhibited a positive level of change from the pre-treatment trend patterns. In terms of food and business employment, the result mirrors the visual trends analyses of employment that show a clear jump after construction.

With respect to wage levels, the ITS estimations show that the street improvement on the Broad Avenue corridor did not have a significant effect on retail wages. In the food service industry, on the other hand, all coefficients are significant, again indicating a negative level change combined with a positive growth trend. Finally, when we examined the combined total wages, the ITS estimations show non-significant results on the level of total wages, but a positive significant increase in the slope (or growth) of overall wages.

Table 8-33. Broad Avenue ITS Regression Results (QCEW data)

Broad Ave. Corridor Interrupted Time Series Estimates (Employment)

	Dependent variable:		
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.
ts_year	1.714*	3.929	5.643
	(0.873)	(4.016)	(4.764)
prepost	25.893**	115.750**	141.643**
	(10.512)	(48.363)	(57.368)
ts_year:prepost	-1.964	-6.607	-8.571
	(1.235)	(5.68)	(6.737)
Constant	-4.143	4.714	0.571
	(3.904)	(17.962)	(21.306)
Observations	14	14	14
R^2	0.826	0.8	0.812
Adjusted R^2	0.774	0.74	0.756
Residual Std. Error (df = 10)	4.619	21.252	25.209
F Statistic (df = 3; 10)	15.813***	13.331***	14.443***
Note:			*p<0.1; p<0.05;* p<0.01

Broad Ave. Corridor Interrupted Time Series Estimates (Wage)

	Dependent variable:		
	CNS07 Retail Wage	CNS18 Food Wage	business 'Business' Wage
ts_year	63,133.96**	44,084.93***	107,218.9***
	(20,125.89)	(10,417.93)	(22,309.48)
prepost	113,153.2	-498,235.4***	-385,082.1
	(242,347.8)	(125,448.5)	(268,641.7)
ts_year:prepost	-3,807.143	101,212.7***	97,405.57**
	(28,462.3)	(14,733.18)	(31,550.37)
Constant	-152,976.4	5,248.286	-147,728.1
	(90,005.7)	(46,590.41)	(99,771.02)
Observations	14	14	14
R^2	0.909	0.992	0.984
Adjusted R^2	0.882	0.989	0.98
Residual Std. Error (df = 10)	106,496.2	55,126.52	118,050.7
F Statistic (df = 3; 10)	33.271***	398.364***	208.592***
Note:			*p<0.1; p<0.05;* p<0.01

8.2.2.4 NETS Data

8.2.2.4.1 Aggregated Trend Analysis

The following tables and figures present the employment and sales change before and after the street improvement on the Broad Avenue corridor using the NETS dataset. As described previously in the data section, economic data from two types of industry categories are presented here: Type I includes all retail and food service establishments on the abutting blocks of the corridor, and Type II includes a refined subset of establishments directly facing the corridor (block-face establishments). Since the treatment and control corridors in this particular scenario are neighboring streets parallel to each other, Type I block level-data on the two corridors may include overlapping establishments.

In terms of the Type I industry (directly corresponding to LEHD industry categories), retail employment and sales started decreasing in 2009, one year before the construction, coinciding with the economic recession period. Retail employment and sales along the treatment corridor decreased sharply compared to the trends on the control corridors and the city. However, while the retail industry was lagging behind on Broad Avenue, we observed a substantial jump in food services employment and sales immediately after the street improvement. Additionally, food service employment per establishment dropped slightly after the bike lane installation, possibly indicating a shift towards smaller establishments along this corridor.

When we analyzed the more refined Type II block-face-level establishments, we found that the employment and sales trends generally follow similar trends as the Type I employment and sales trends. Prior to 2009, retail employment and sales were generally increasing; after 2009, the trends showed decreasing tendencies. The Type II food service sector, on the other hand, displayed substantial increases in employment and sales following the street improvement on Broad Avenue.

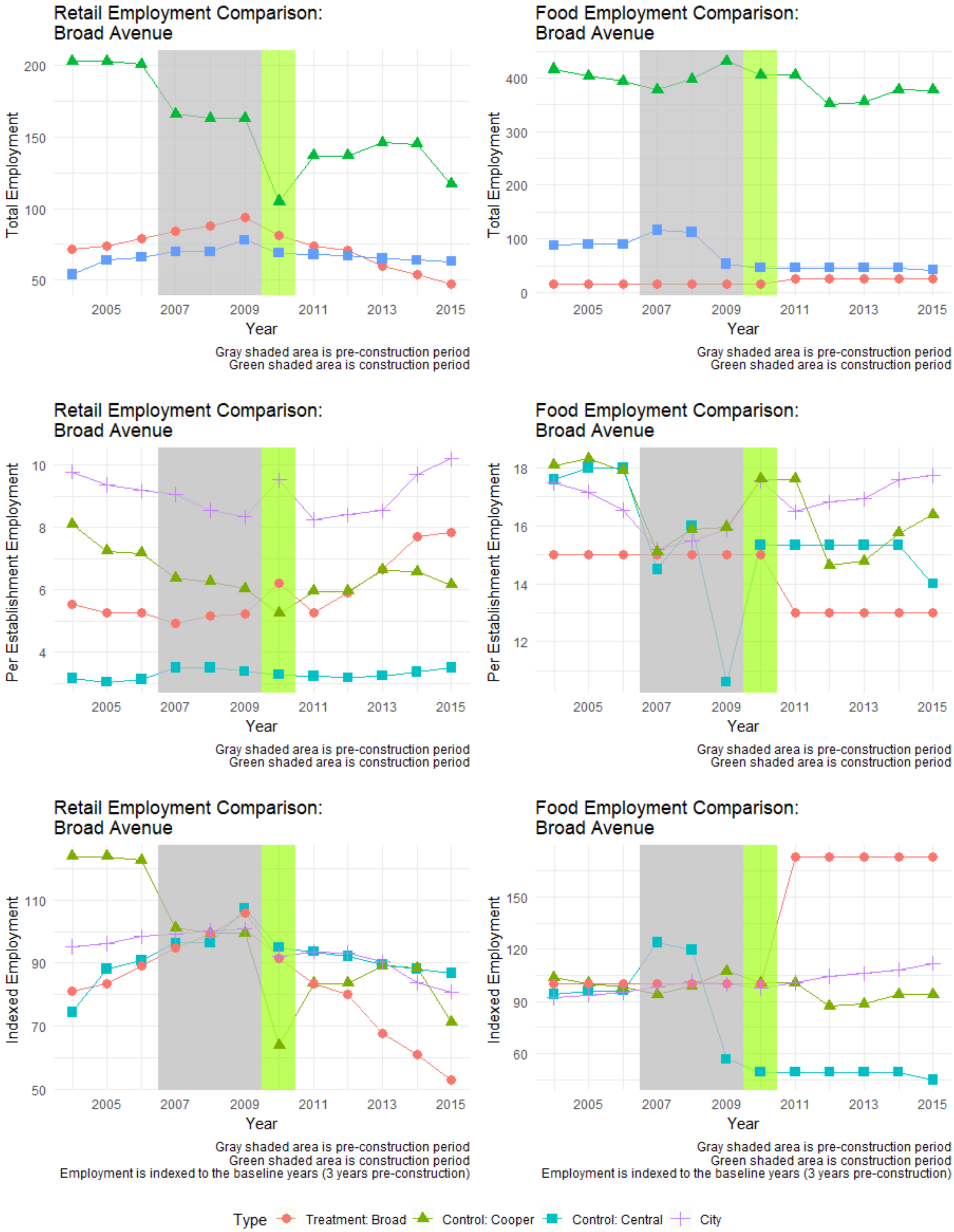


Figure 8-21. Aggregated Employment Trend of Broad Avenue and Control Corridors by NETS Data – Industry Type I

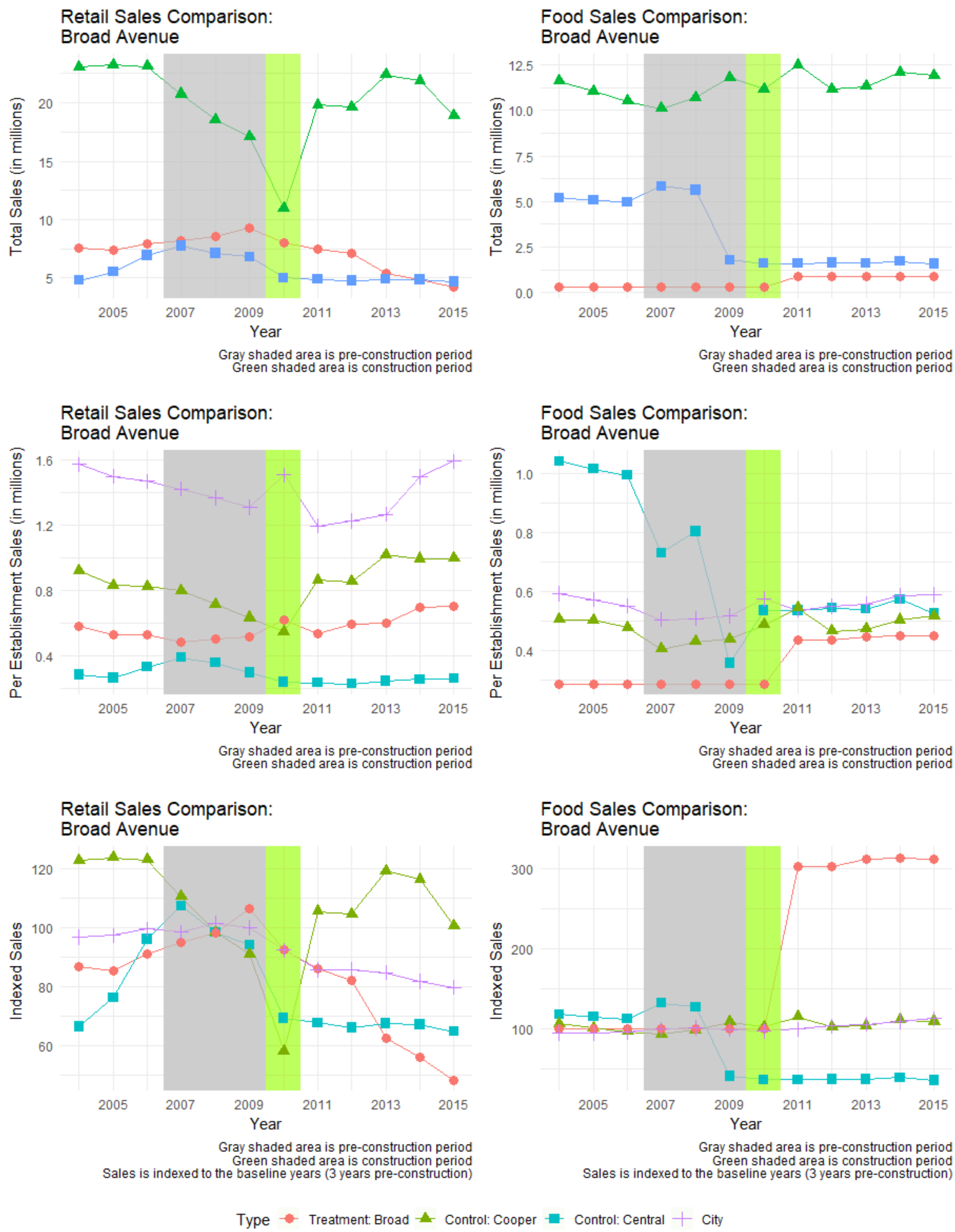


Figure 8-22. Aggregated Sales Trend of Broad Avenue and Control Corridors by NETS Data – Industry Type I

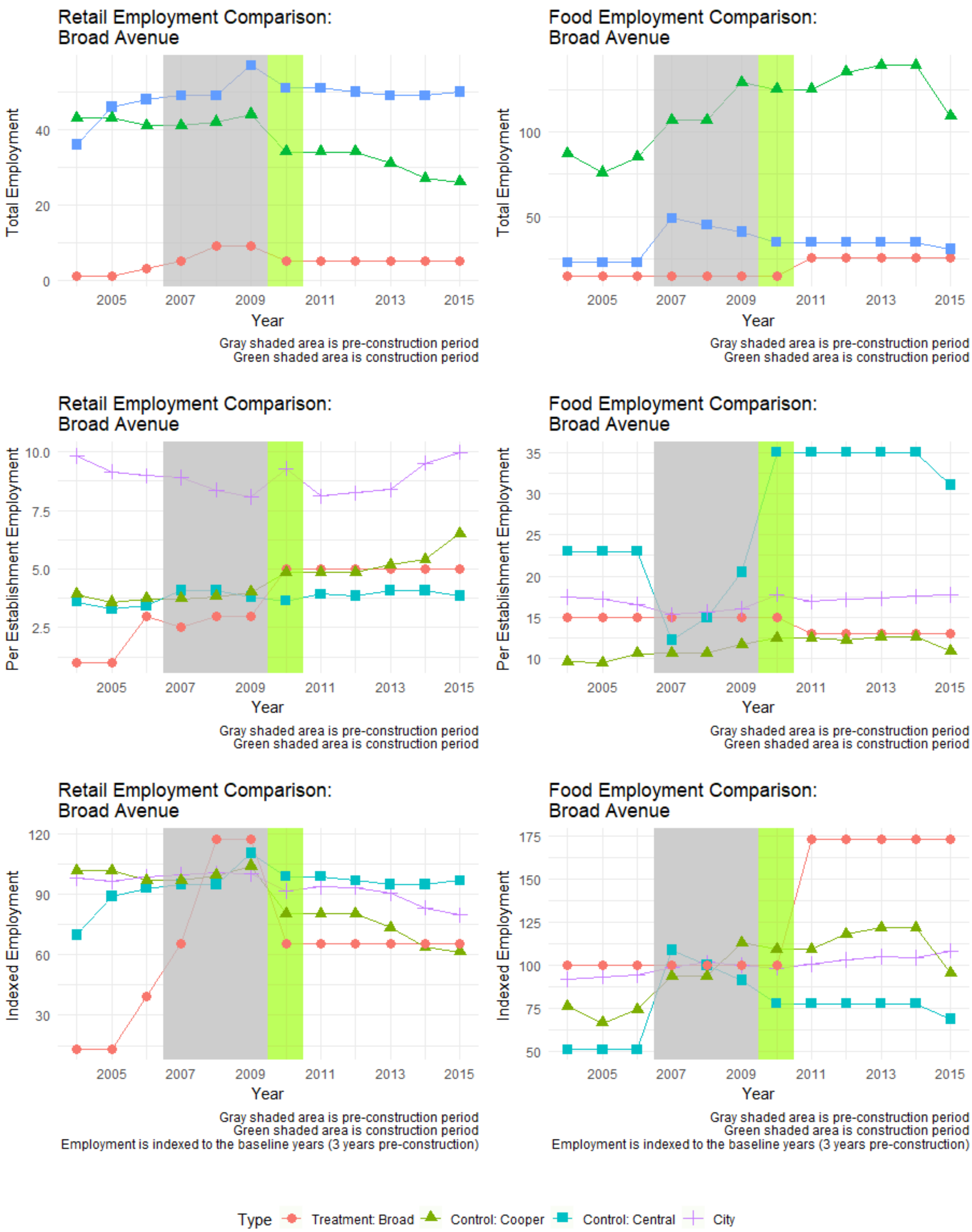


Figure 8-23. Aggregated Employment Trend of Broad Avenue and Control Corridors by NETS Data – Industry Type II

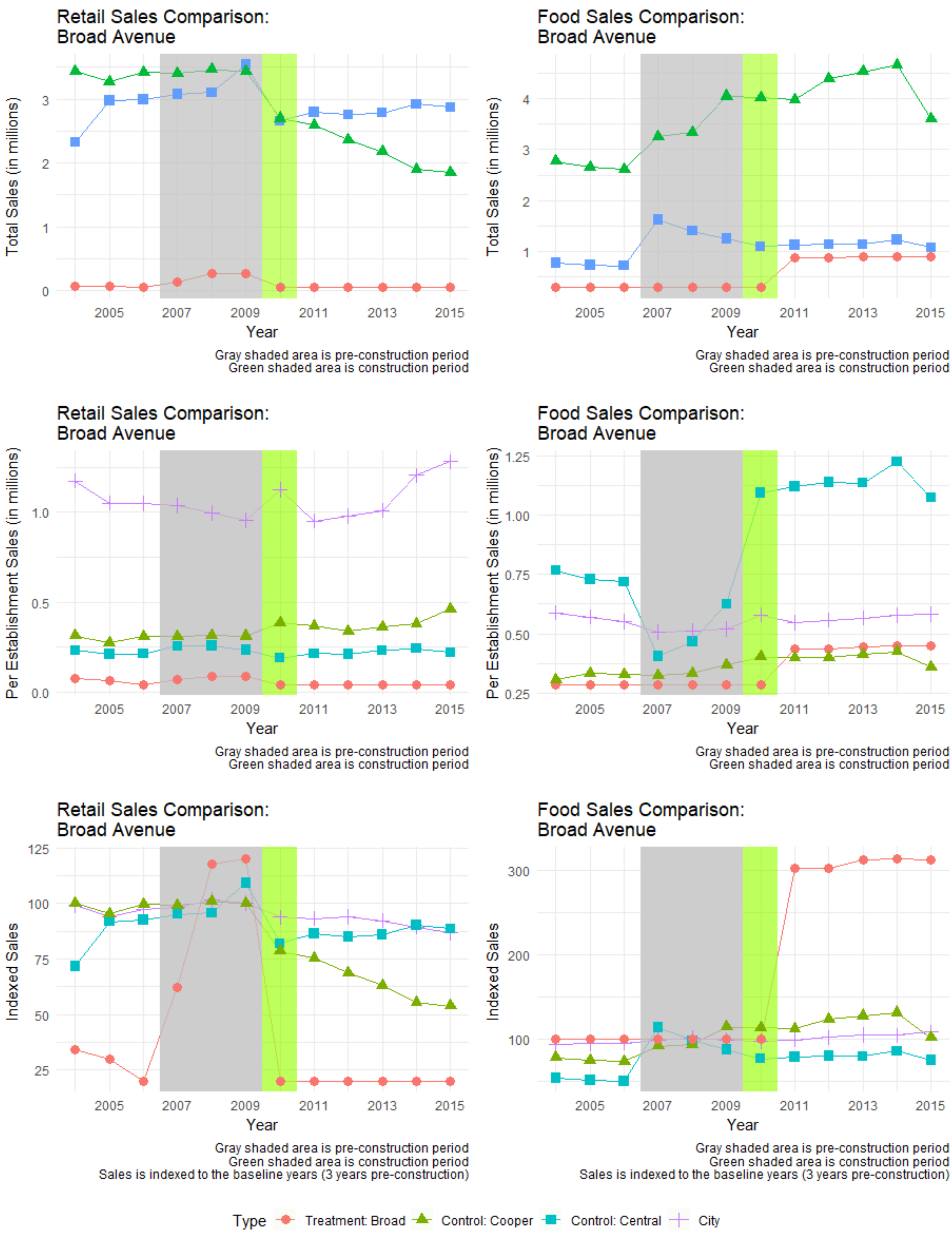


Figure 8-24. Aggregated Sales Trend of Broad Avenue and Control Corridors by NETS Data – Industry Type II

Table 8-34. Broad Avenue Trend Analysis Summary Table (NETS)

	Retail Baseline		Post-implementation				Food Baseline		Post-implementation			
Area	**Base**	**Growth**	**1st Year**	**2nd Year**	**3rd Year**	**Average**	**Base**	**Growth**	**1st Year**	**2nd Year**	**3rd Year**	**Average**
NETS: (employment, type1)												
Treatment	89	5.79%	-16.85%	-4.05%	-15.49%	-12.13%	15	0.00%	73.33%	0.00%	0.00%	24.44%
Control: Cooper	164	-0.90%	-16.46%	0.00%	6.57%	-3.30%	402	6.80%	0.75%	-13.33%	1.14%	-3.82%
Control: Central	73	5.71%	-6.85%	-1.47%	-2.99%	-3.77%	94	-28.06%	-51.06%	0.00%	0.00%	-17.02%
NETS: (employment, type2)												
Treatment	9	5.93%	-16.99%	-4.42%	-24.17%	-15.19%	-	0.00%	N/A	0.00%	2.94%	N/A
Control: Cooper	19	-9.24%	4.26%	-0.89%	14.01%	5.79%	11	8.16%	13.53%	-10.74%	1.51%	1.43%
Control: Central	7	-6.30%	-29.96%	-2.30%	2.05%	-10.07%	4	-35.97%	-59.92%	1.69%	-0.74%	-19.65%
NETS: (sales, type1)												
Treatment	8	40.00%	-37.50%	0.00%	0.00%	-12.50%	15	0.00%	73.33%	0.00%	0.00%	24.44%
Control: Cooper	42	3.60%	-19.05%	0.00%	-8.82%	-9.29%	114	10.28%	9.65%	8.00%	2.96%	6.87%
Control: Central	52	8.16%	-1.92%	-1.96%	-2.00%	-1.96%	45	-8.53%	-22.22%	0.00%	0.00%	-7.41%
NETS: (sales, type2)												
Treatment	-	45.65%	N/A	0.00%	0.00%	N/A	-	0.00%	N/A	0.00%	2.94%	N/A
Control: Cooper	3	0.35%	-13.67%	-8.68%	-8.23%	-10.20%	4	11.98%	-0.38%	10.12%	3.21%	4.32%
Control: Central	3	7.35%	-6.74%	-1.60%	1.16%	-2.39%	1	-12.20%	12.00%	1.56%	-0.21%	4.45%

1 Baseline is defined as the average of previous three years before construction year;
2 Pre-growth rate is defined as average of baseline annual growth rate;
3 1st year growth rate is defined as the growth rate of the year after construction compared to baseline.

8.2.2.4.2 Difference-in-Difference (DID) Analysis

DID estimations of the NETS dataset are presented below. Since the NETS dataset has longer historical data, we chose to use the data between 2004 and 2015 for our analysis to maintain consistency, and limit this analysis to only the Type II establishments as these are the businesses that directly face the street improvement corridor. We find mixed results depending on the control corridors and industry types. In the case of the retail employment and sales, Cooper Street had a significant negative DID estimator while those of Central Avenue were not significant. This means that retail activity on the Broad Avenue treatment corridor decreased less than that of Cooper Street. In the case of the food service industry and the combined business sector, there were more ambiguous results depending on the economic indicator and control corridors.

Table 8-36. Broad Avenue DID Regression Results (NETS, Type I)

Broad Avenue Corridor Difference-in-Difference Estimates (Type I)

	Dependent variable:					
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.	CNS07 Retail Sales	CNS18 Food Sales	business 'Business' Sales
TypeControl: Central Ave	-14.429 (9.4)	70.000*** (8.7)	2.174* (1.3)	-1.836 (1.2)	4.010*** (0.5)	55.571*** (12.3)
TypeControl: S Cooper St	90.286*** (9.4)	388.429*** (8.7)	22.094*** (1.3)	11.397*** (1.2)	10.697*** (0.5)	478.714*** (12.3)
prepost	-20.514* (10.3)	11 (9.5)	-1.704 (1.4)	-2.303* (1.3)	0.599 (0.5)	-9.514 (13.5)
TypeControl: Central Ave:prepost	18.629 (14.5)	-50.800*** (13.4)	-2.422 (2.0)	0.844 (1.8)	-3.265*** (0.7)	-32.171 (19.1)
TypeControl: S Cooper St:prepost	-15.086 (14.5)	-41.229*** (13.4)	3.503* (2.0)	3.301* (1.8)	0.202 (0.7)	-56.314*** (19.1)
Constant	81.714*** (6.6)	15.000** (6.1)	8.408*** (0.9)	8.122*** (0.8)	0.286 (0.3)	96.714*** (8.7)
Observations	36	36	36	36	36	36
R^2	0.878	0.992	0.962	0.91	0.971	0.99
Adjusted R^2	0.858	0.991	0.955	0.894	0.967	0.988
Residual Std. Error (df = 30)	17.516	16.204	2.387	2.229	0.875	23.085
F Statistic (df = 5; 30)	43.167***	749.717***	150.779***	60.329***	204.212***	576.683***
Note:						*p<0.1; p<0.05; p<0.01*

Table 8-35. Broad Avenue DID Regression Results (NETS, Type II)

Broad Avenue Corridor Difference-in-Difference Estimates (Type II)

	Dependent variable:					
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.	CNS07 Retail Sales	CNS18 Food Sales	business 'Business' Sales
TypeControl: Central Ave	43.286*** (2.0)	19.143*** (6.1)	3.621*** (0.2)	2.824*** (0.1)	0.796*** (0.2)	62.429*** (6.7)
TypeControl: S Cooper St	36.429*** (2.0)	87.286*** (6.1)	6.132*** (0.2)	3.177*** (0.1)	2.955*** (0.2)	123.714*** (6.7)
prepost	0.286 (2.2)	11 (6.7)	0.516** (0.2)	-0.082 (0.1)	0.599*** (0.2)	11.286 (7.3)
TypeControl: Central Ave:prepost	1.514 (3.2)	-10.943 (9.5)	-0.586 (0.4)	-0.043 (0.2)	-0.543* (0.3)	-9.429 (10.3)
TypeControl: S Cooper St:prepost	-11.029*** (3.2)	16.114* (9.5)	-0.652* (0.4)	-1.046*** (0.2)	0.394 (0.3)	5.086 (10.3)
Constant	4.714*** (1.4)	15.000*** (4.3)	0.413** (0.2)	0.126 (0.1)	0.287** (0.1)	19.714*** (4.7)
Observations	36	36	36	36	36	36
R^2	0.967	0.942	0.975	0.973	0.949	0.954
Adjusted R^2	0.961	0.933	0.97	0.969	0.941	0.946
Residual Std. Error (df = 30)	3.805	11.431	0.425	0.244	0.354	12.47
F Statistic (df = 5; 30)	175.439***	97.830***	231.074***	220.020***	111.907***	123.894***
Note:						*p<0.1; p<0.05; p<0.01*

8.2.2.4.3 Interrupted Time Series (ITS) Analysis

Similar to DID analysis, we only conducted the ITS analysis on Type II block-face-level establishments using NETS data, and chose to utilize only the data between 2004 and 2015 for this analysis. The models indicate that the street improvement had no significant impact on retail employment and sales on Broad Avenue. However, the bike lane installation led to positive significant increases in food service employment and food and business sales in most cases.

Table 8-38. Broad Avenue ITS Regression Results (NETS, Type I)

Broad Avenue Corridor Interrupted Time Series Estimates (Type I)

	Dependent variable:					
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.	CNS07 Retail Sales	CNS18 Food Sales	business 'Business' Sales
ts_year	2.714**	-0.000**	0.206**	0.206**	0	2.714**
	(0.9)	(0.0)	(0.1)	(0.1)	(0.0)	(0.9)
prepost	61.343***	11.000***	7.847***	7.336***	0.511***	72.343***
	(14.9)	(0.0)	(1.5)	(1.5)	(0.0)	(14.9)
ts_year:prepost	-9.814***	0	-1.078***	-1.087***	0.009***	-9.814***
	(1.7)	(0.0)	(0.2)	(0.2)	(0.0)	(1.7)
Constant	70.857***	15.000***	7.586***	7.300***	0.287***	85.857***
	(3.8)	(0.0)	(0.4)	(0.4)	(0.0)	(3.8)
Observations	12	12	12	12	12	12
R^2	0.923	1	0.917	0.94	1	0.858
Adjusted R^2	0.894	1	0.886	0.917	1	0.804
Residual Std. Error (df = 8)	4.498	0	0.441	0.443	0.005	4.498
F Statistic (df = 3; 8)	31.929***	12,116,378,689,967,43 4,972,966,632,040,200	29.609***	41.420***	12,497.840***	16.055***
Note:						*p<0.1; **p<0.05**; p<0.01*

Table 8-37. Broad Avenue ITS Regression Results (NETS, Type II)

Broad Avenue Corridor Interrupted Time Series Estimates (Type II)

	Dependent variable:					
	CNS07 Retail Emp.	CNS18 Food Emp.	business 'Business' Emp.	CNS07 Retail Sales	CNS18 Food Sales	business 'Business' Sales
ts_year	1.214***	-0.000**	0.018	0.018	0	1.214***
	(0.3)	(0.0)	(0.0)	(0.0)	(0.0)	(0.3)
prepost	5.143	11.000***	0.502*	-0.009	0.511***	16.143**
	(6.0)	(0.0)	(0.3)	(0.3)	(0.0)	(6.0)
ts_year:prepost	-1.214	0	-0.01	-0.018	0.009***	-1.214
	(0.7)	(0.0)	(0.0)	(0.0)	(0.0)	(0.7)
Constant	-0.143	15.000***	0.339***	0.053	0.287***	14.857***
	(1.5)	(0.0)	(0.1)	(0.1)	(0.0)	(1.5)
Observations	12	12	12	12	12	12
R^2	0.614	1	0.944	0.387	1	0.94
Adjusted R^2	0.469	1	0.923	0.158	1	0.918
Residual Std. Error (df = 8)	1.808	0	0.076	0.076	0.005	1.808
F Statistic (df = 3; 8)	4.236**	12,116,378,689,967,43 4,972,966,632,040,200	42.104***	12,497.840***	45.173***	1.686
Note:						*p<0.1; **p<0.05**; p<0.01*

8.2.3 Distributional Analysis

The distributional analysis aims to track the demographic changes of residents along the treatment corridor, control corridors and the city as a whole before and after the bike lane installation to examine any potential equity outcomes of the bike lane installation on the Broad Avenue corridor. This analysis is conducted using the LEHD dataset, where income indicators are available for a longer time period (covering both the pre- and post-construction periods), while gender, race and education indicators are only available starting in 2009.

8.2.3.1 Income

The Broad Avenue corridor experienced a significant drop in total employment as well as high-income employment during the 2005-2007 period. Following this decrease, the treatment corridor has maintained constant levels of employment and income composition. The total employment on the Central Avenue control corridor increased gradually after 2010, but with no particular changes in the income composition. A similar pattern also existed on the Cooper Street control corridor, although there was more middle-income employment. Cooper Street's income composition also remained relatively constant across the years. In general, we do not observe much difference in the income composition trends between the treatment and control corridors after the bike lane installation on Broad Avenue.

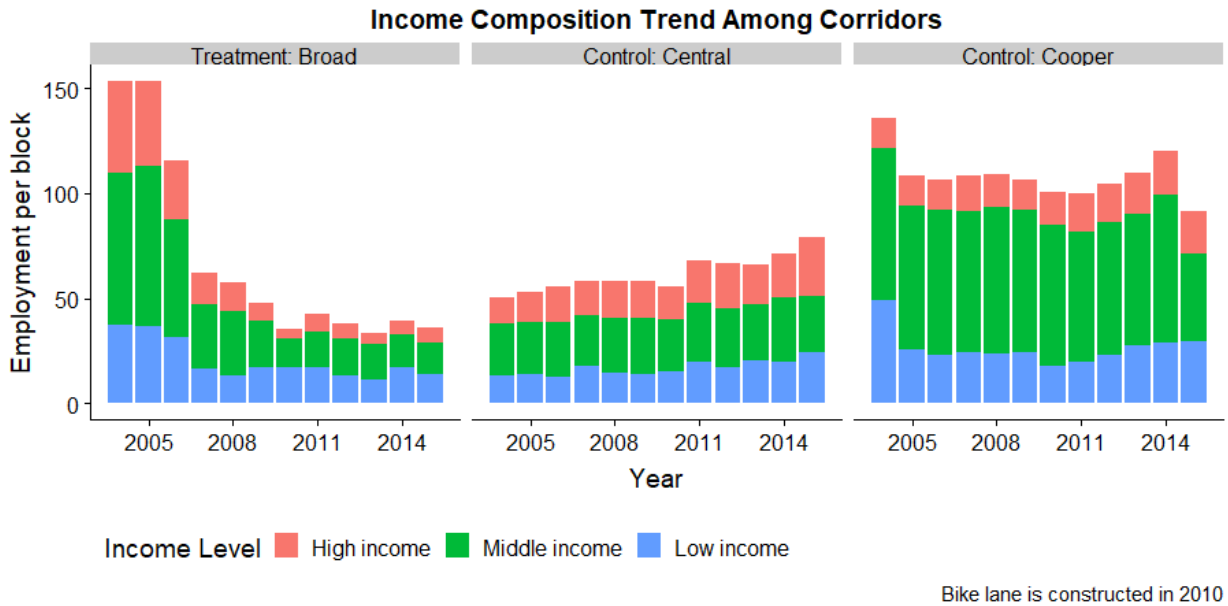


Figure 8-25. Broad Avenue Income Employment Level Composition Trend

8.2.3.2 Race

8.2.3.2.1 Employment

In terms of employment racial composition, there was a higher level of white employment and a lower level of black employment on the treatment and control corridors when compared to the overall city average. On the treatment corridor, the percentage of white employment decreased slightly, and black employment increased slightly during the analysis time period. This trend matches the city average trend. Central Avenue experienced the opposite trend in the percentage of white and black employment than the treatment corridor, while the employment racial composition on Cooper Street remained relatively constant. However, changes in employment racial composition across all corridors is minimal.

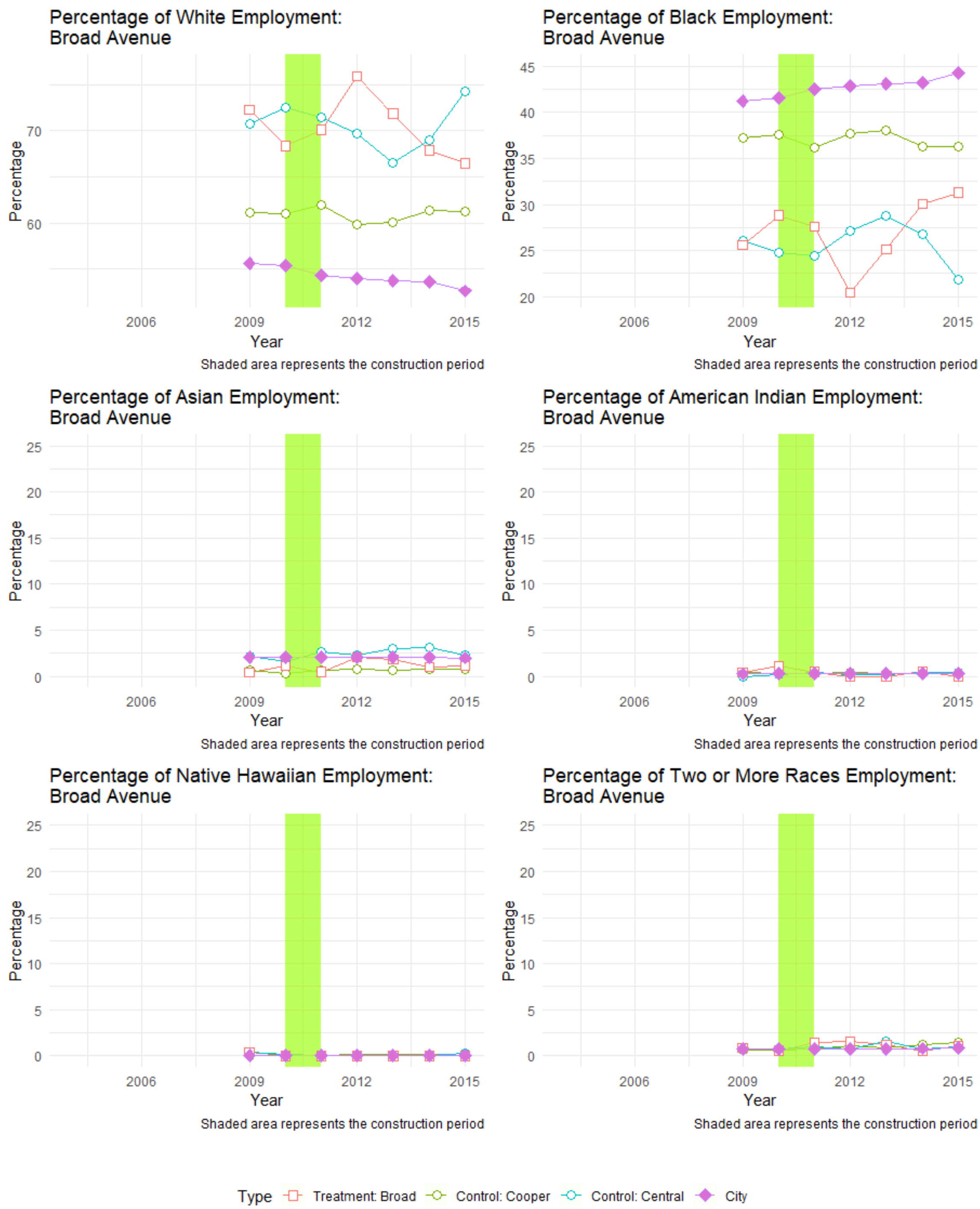


Figure 8-26. Broad Avenue Employment Racial Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 8-23 summarizes the percentage change of employment racial composition for the Broad Avenue corridor group. One thing to note is that, due to the lower number of some groups, the percentage change may look very large even when the actual employment changes are small.

Table 8-39. Broad Avenue Employment Racial Composition Percentage Change (in percentage)

	Treatment: Broad	Control: Central	Control: Cooper	City
White	-1.33	0.84	0.04	-0.89
Black	3.67	-2.71	-0.39	1.19
American Indian	-16.67	NA	-4.61	1.55
Asian	27.65	0.41	2.62	-0.41
Hawaiian	-16.67	-4.33	-16.67	-3.21
Two or more races	5.49	8.01	19.35	1.51

Note: These percentage changes are calculated as the average annual percentage change between 2011 and 2015.

8.2.3.2.2 Residents

Similar to the employment racial composition patterns, there are more white residents and fewer black residents on the analyzed corridors than the city average. The number of white and black residents on the treatment corridor both remained constant or decreased slightly, similar to the patterns observed on Cooper Street and in the city. However, the other control corridor – Central Avenue – saw a great increase in white residents and a significant drop in black residents. There was also an increase in Asian residents on the treatment corridor, which was not observed on the control corridors or in the city.

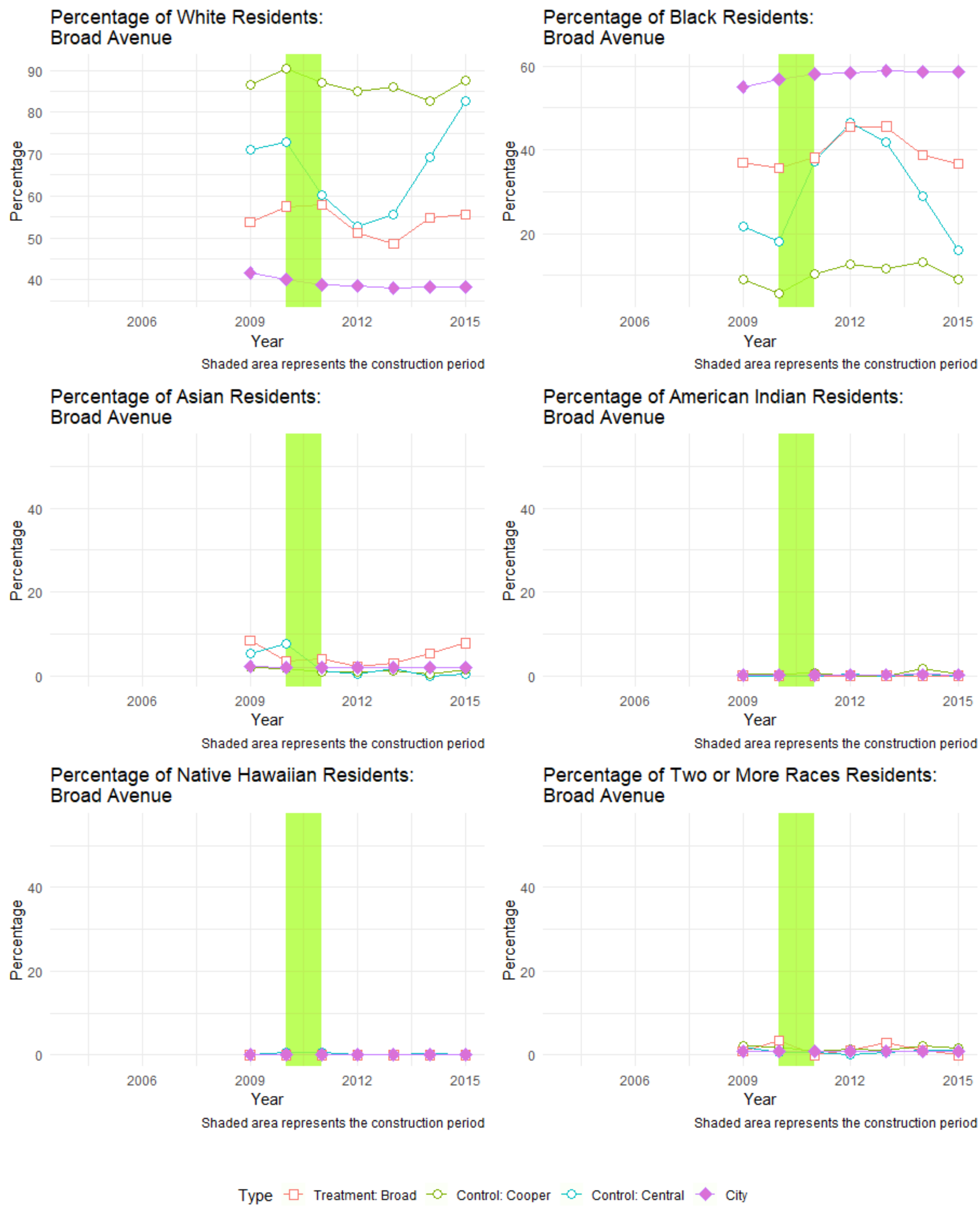


Figure 8-27. Broad Avenue Residents Racial Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 8-40. Broad Avenue Residents Racial Composition Percentage Change (in percentage)

	Treatment: Broad	Control: Central	Control: Cooper	City
White	-1.01	9.34	0.10	-0.25
Black	-0.97	-14.33	-2.96	0.21
American Indian	NA	NA	-13.65	2.20
Asian	24.25	-17.68	12.83	-2.11
Hawaiian	NA	-25.00	NA	3.10
Two or more races	NA	18.88	20.40	1.53

Note: These percentage changes are calculated as the average annual percentage change between 2011 and 2015.

8.2.3.3 Education

8.2.3.3.1 Employment

In terms of education attainment, the treatment corridors had less college and bachelor’s level employment than the city as a whole. Due to the fuzzy factor applied in LEHD data, there are some unexpected fluctuations in the annual trends. In general, the treatment corridor has similar patterns as the corresponding control corridors.

8.2.3.3.1 Residents

In terms of residents’ education level, the trend for the treatment corridor fluctuates more. In general, there were more residents with college educational attainment and fewer residents with bachelor’s attainment when compared to the city as well as the control corridors. This might indicate a shift in the industrial sectors that exist along the treatment corridors and neighboring areas, with more jobs that require less education or non-conventional education.

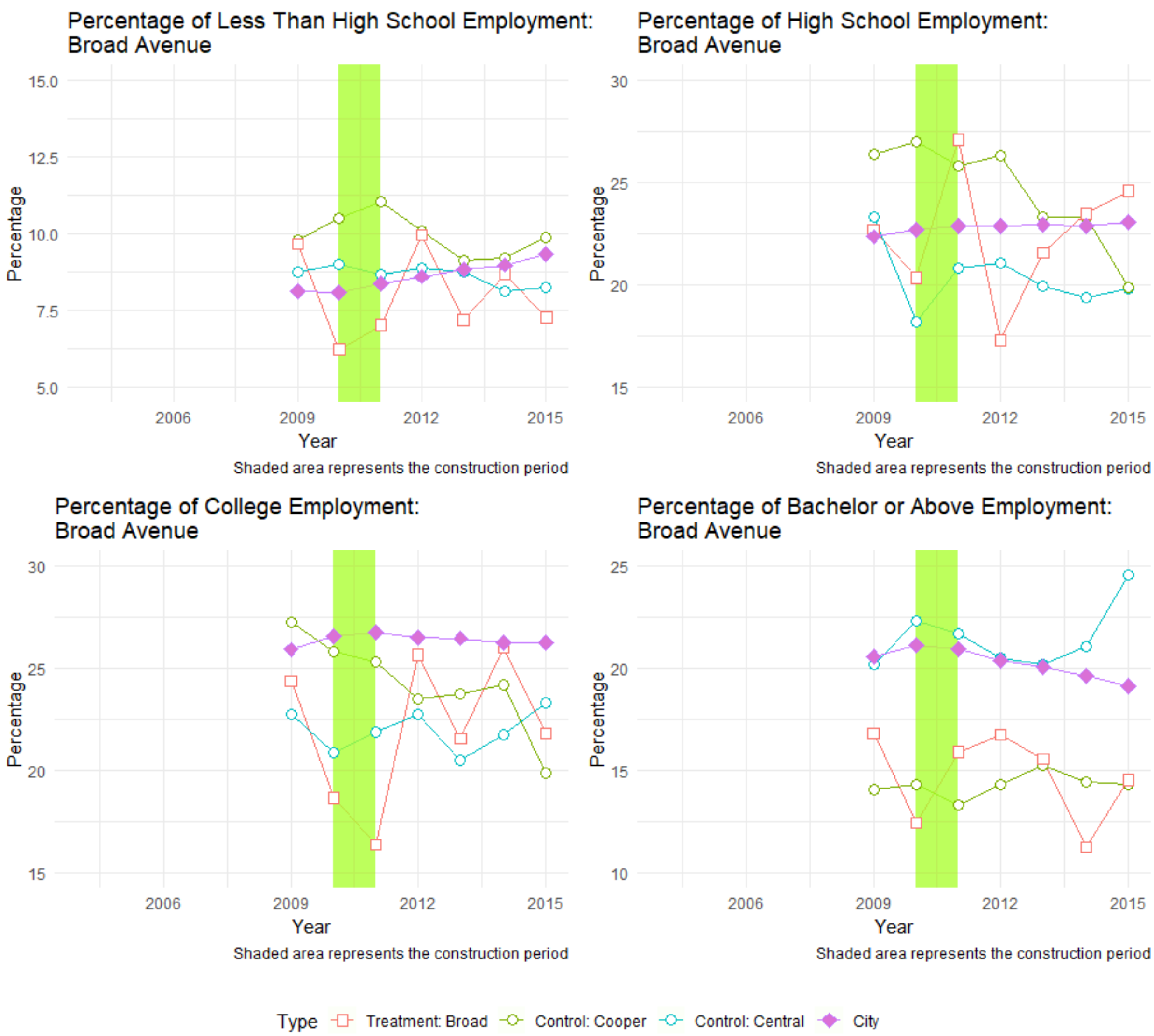


Figure 8-28. Broad Avenue Employment Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 8-41. Broad Avenue Employment Education Level Composition Percentage Change (in percentage)

	Treatment: Broad	Control: Central	Control: Cooper	City
Less than high school	0.60	-0.79	-1.78	1.94
High school	-1.55	-0.84	-3.82	0.16
College	5.53	1.12	-3.58	-0.31
Bachelor’s or above	-1.42	2.21	1.31	-1.42

Note: These percentage changes are calculated as the average annual percentage change between 2011 and 2015.

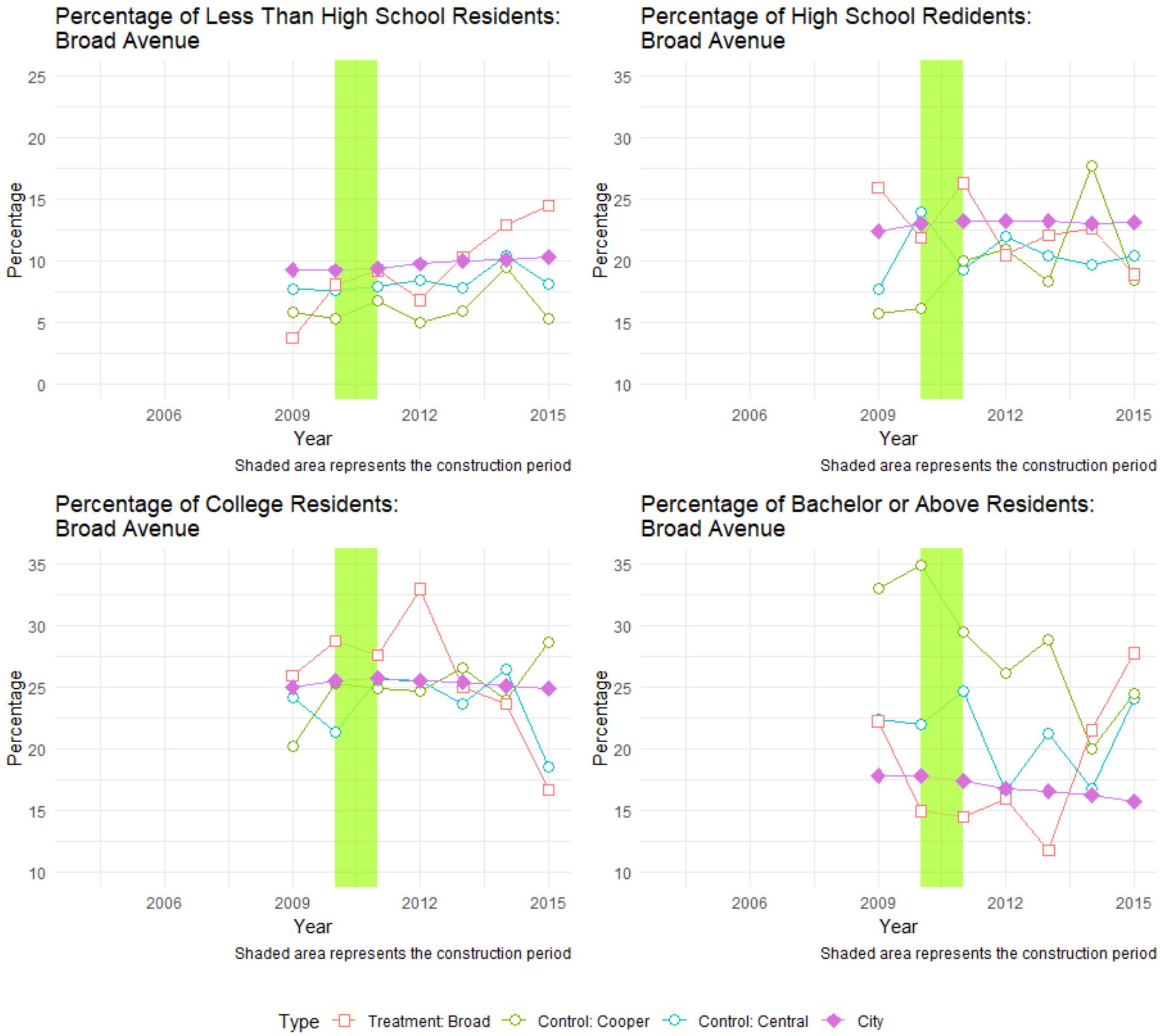


Figure 8-29. Broad Avenue Residents Education Level Composition Trend
(Note: For consistency, all graphs have the same y-axis scale, but with different starting points.)

Table 8-42. Broad Avenue Residents Education Level Composition Percentage Change (in percentage)

	Treatment: Broad	Control: Central	Control: Cooper	City
Less than high school	14.20	0.74	-5.39	2.54
High school	-7.05	1.38	-1.94	-0.18
College	-9.92	-6.93	3.86	-0.74
Bachelor’s or above	22.98	-0.61	-9.92	-2.43

Note: These percentage changes are calculated as the average annual percentage change between 2011 and 2015.

8.2.3.4 Gender

The treatment corridor experienced decreases in female employment, while the female employment did not experience the same decreases on control corridors. On the other hand, the resident gender composition remained relatively constant across different corridors.

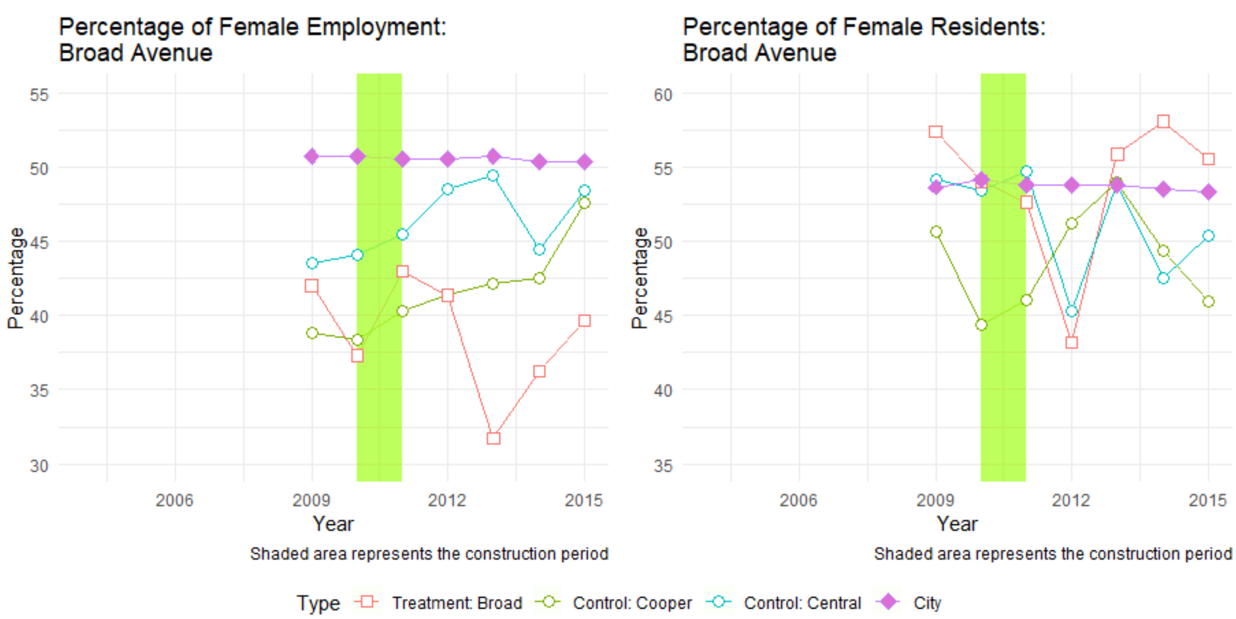


Figure 8-30. Broad Avenue Gender Composition Trend

In general, construction of the bike lane on the Broad Avenue corridor did not appear to result in any clear demographic changes compared to the corresponding control corridors or the city as a whole. The few noticeable patterns include less black employment and female employment on the treatment corridor after the bike lane installation compared to the control corridors, and lower education attainment employment compared to the city. We found that the treatment corridor generally followed similar trends of racial composition changes as the city and its control corridors. This preliminary distributional equity analysis of the demographic patterns along the Broad Avenue improvement corridor should not be considered as a definitive indication that there are no equity or distributional concerns, and could benefit from additional research.

8.2.4 Broad Avenue Summary

We used four different data sources, LEHD employment data, retail sales tax data, QCEW data and NETS employment and sales revenue data, to analyze the economic and equity impacts of street improvement on the Broad Avenue corridor. Each of these data sources was analyzed using the aggregated trend analysis, DID estimation and ITS estimation approaches, and we were able to conclude that:

- The Broad Avenue corridor shows some contradictory patterns where its retail LEHD employment experienced large decreases but the sales tax receipts and QCEW retail employment increased following the bike lane installation. These mixed results may be due to the fuzzed LEHD data and the different industrial coverage and geographical scales of these data sources.
- There is consistent evidence for positive impacts of the street improvement on food employment on Broad Avenue, supported by the aggregated trend analysis and ITS estimation results across both the LEHD and QCEW employment data sources.
- The environmental justice indicators on Broad Avenue generally followed a similar trend as the control corridors and the city. We did not observe any significant divergent patterns in demographic trends along the street improvement corridor when compared with the control corridors or the city.

9.0 CROSS-VALIDATION

Cross-validation methods can be applied to test the validity of the chosen dependent variables (e.g., employment, business revenues, etc.) and the applicability and robustness of our methodological framework to other cities. Ideally, treatment and control corridor pairs would be tested to examine the robustness of research findings. We were unable to identify additional corridors for cross-validation in our study cities at the current time, as many street improvement corridors were constructed more recently. Therefore, we propose two cross-validation approaches below, for future validation when there are appropriate corridors and available data.

The first common approach to evaluate model prediction is to create a scatterplot of observed versus predicted values (Piñeiro et al., 2008). In our case, the actual values would be the post-implementation employment or sales in the treatment corridor, while the predicted values would be the fitted values from our estimated DID or ITS models. Ideally, all the points should be close to a diagonal 1:1 line to indicate a highly predictive model. For example, if the actual employment is 10, the predicted employment should also be close to 10. Weaker models will show more dispersion of points away from the 1:1 diagonal line.

The second approach is to calculate predicted residual error sum of square (PRESS) statistics, which is an estimate of overall predictive ability (Picard et al., 1984). It is a commonly used cross-validation approach for regression analysis to provide a summary measure of the fit of the model. The PRESS statistic is equal to the sum of the squares of all differences between predicted and observed values, and lower PRESS values indicate better model fit when comparing between different regression models.

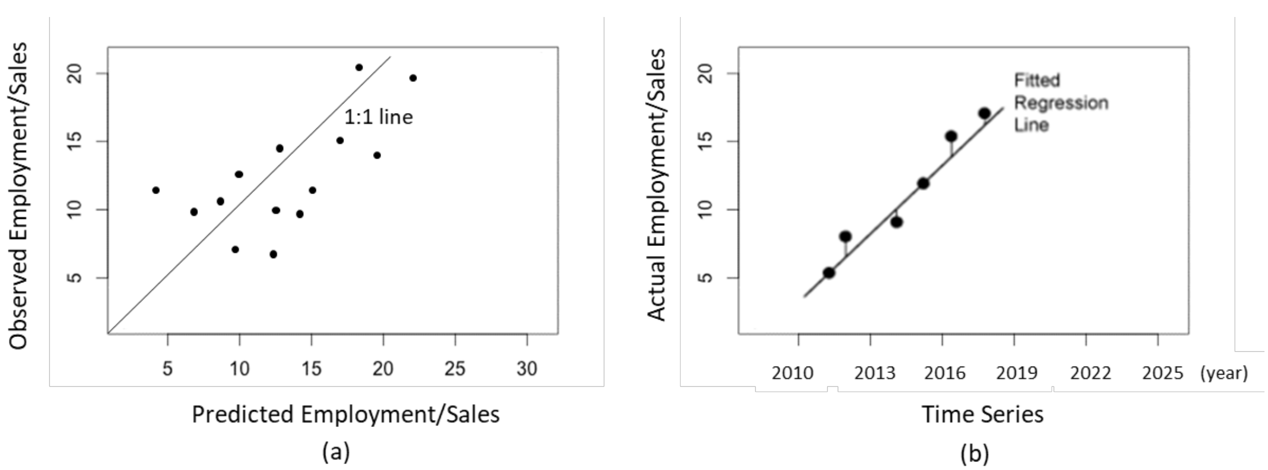


Figure 9-1. Cross-Validation Approaches Illustration (a – Actual vs. predicted graphs; b - PRESS)

DISCUSSION OF DATA SOURCES AND METHODOLOGIES

9.1 DATA SOURCE COMPARISON

Table 10-1 summarizes the economic and business impacts of street improvement corridors for bicycle and pedestrian mobility across all study corridors by different data sources and methodologies. Previous sections of this report contain further details of the analysis results, interpretations and other considerations. This table serves to provide an overview of the differences that result from the usage of data sources that include different economic indicators, have different geographic details and include different categorizations of industries. The advantages and disadvantages of utilizing these data sources within the context of street improvements are discussed below.

Table 10-1. Economic Impacts of Study Corridors Summary

Corridor	Data Source	Methodology Aggregated Trend		DID		ITS	
		Retail	Food	Retail	Food	Retail	Food
Portland, OR							
Stark & Oak Ave.	LEHD	o	+	+	o	o	+
	Retail Sales						
	QCEW	+	+	o	o	+	o
	NETS	+	o	+	+	+	o
San Francisco, CA							
Polk St.	LEHD	o	o	o	o	+	o
	Retail Sales	+	+	+	+	o	o
	QCEW						
	NETS	+	o	+	+	+	o
17th St.	LEHD	+	-	-	-	+	o
	Retail Sales						
	QCEW						
	NETS	+	-	+	-	o	o
Minneapolis, MN							
Central Ave.	LEHD	o	o	o	-	+	+
	Retail Sales	+	+	+	-	o	+
	QCEW	+		o		+	
	NETS	o	o	o	o	o	o
Franklin Ave.	LEHD	-	+	+	o	o	+
	Retail Sales						
	QCEW	o		o		o	

Corridor	Data Source	Methodology Aggregated Trend		DID		ITS	
		Retail	Food	Retail	Food	Retail	Food
Memphis, TN	NETS	-	o	-	+	o	o
Madison Ave.	LEHD	o	o	o	o	o	+
	Retail Sales	+	+	o	o	+	+
	QCEW	o	+	o	o	+	+
	NETS	o	o	o	o	o	o
Broad Ave.	LEHD	-	+	-	o	o	+
	Retail Sales	+	+	o	o	+	+
	QCEW	+	+	o	o	+	+
	NETS	o	+	o	o	o	+

Notes: “+” indicates positive impact; “-” indicates negative impact; “o” indicates not apparent or insignificant impacts; shaded boxes on this table indicate that there was no appropriate data available for that corridor.

First, as we mentioned in the data section, LEHD block-level data is fuzzed for confidentiality. Thus, while aggregating data to the corridor-level data may address this issue to some extent, the data can only reflect general trends in employment along the corridor, and the annual employment numbers should be considered as rough estimations of actual employment. Figure 10-1 illustrates some of the differences between LEHD data and other data sources. As we compared between the LEHD employment with the sales revenues from sales tax data and employment numbers from the NETS dataset on Polk Street in San Francisco, we observed that while the general trends appear to be similar, LEHD data shows more fluctuation than the other two data sources.

In our analysis, economic indicators are typically separated into retail and food services sectors to provide an understanding of how street improvements may have impacted different types of street-level businesses. However, due to the differences in industrial detail or included industries for each data source, some of the economic indicators may be capturing different sets of businesses and establishments. The industry classification in LEHD data only includes employment at the two-digit NAICS code level, which gives us a combination of store and non-store retailers (NAICS code 44-45) as the retail industry, and a combination of food service and accommodation (NAICS code 72) as the food industry. When QCEW data and retail sales tax data is provided by city agencies on a micro-level, we may have the ability to exclude certain irrelevant industry sectors (i.e., gas stations) for analysis. For example, the retail sales data in San Francisco includes only retailers, and the QCEW data from Minneapolis includes businesses in NAICS codes 442-453 as the retail industry. With regards to the NETS dataset, we were able to define more detailed industry categorizations that include business establishments which are most appropriate for this project. We organized the full NETS retail dataset for the street improvement corridors into two industry categories of interest (see Section 3.3 for full details): Type I is more broadly defined as retail and food industries that are located on the city blocks where the street improvement occurs, while Type II includes only a subset of Type I retailers and food services establishments that are directly facing the street improvement corridor. Figure 10-2 shows that the two types of industry types oftentimes can show similar economic trends (e.g., Franklin Avenue in Minneapolis) but, depending on the specific context and specific businesses located on the corridors, sometimes the two industry types may show very different trends (e.g., see Figure 10-3 for 17th Street in San Francisco).

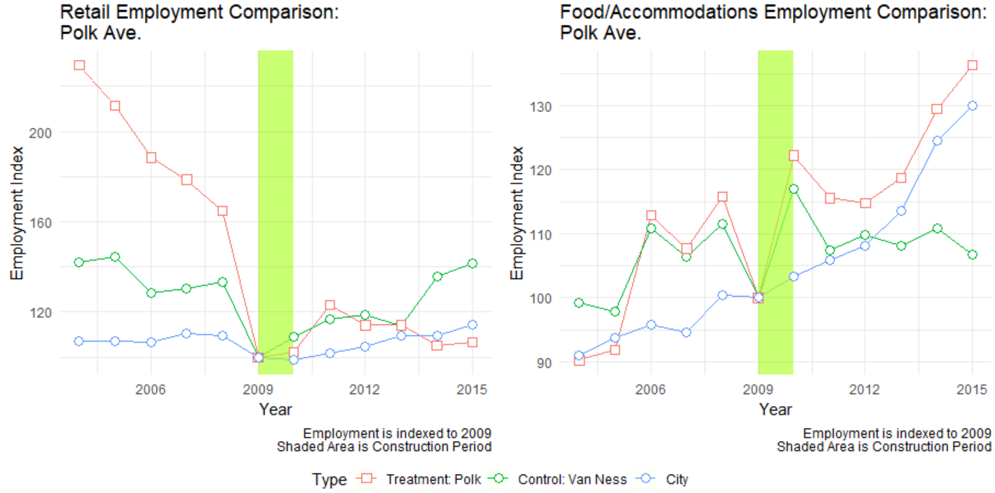
Additionally, the geographical scales may be different for different data sources. As mentioned previously, LEHD data is provided at the census-block level, which means that all the establishments within the abutting blocks of the corridor will be included (including those on the same block but facing another street). However, this type of geographic detail may not provide sufficient accuracy to estimate the economic impacts of street improvement corridors, as those establishments directly facing the corridor are more likely to see changes in traffic than those on the same block but facing other corridors. To ensure that this analysis examines only relevant establishments that have street-level retail storefronts (and not wholesalers of heavy manufacturing machinery that have a storefront, or catering businesses that do not rely on consumer traffic), data sources that allow for this level of disaggregation, industry detail and geographic detail are highly preferred.

Each of the data sources that we utilized in this report have different objectives when the data was collected. For instance, the LEHD data aims to capture overall economic activities as part of the Census Bureau’s data products; however, the QCEW data is intended to track establishments that participate in the unemployment insurance program. Sales tax data, on the other hand, is a dataset that is created directly from the sales tax collection mechanism, and thus the focus is on consumption behaviors (that are reflected in sales tax receipts), rather than employment and wages. In short, it is quite possible that the establishments included in each data source may differ due to differences in the primary purpose of data collection. Therefore, even when considering similar economic indicators such as employment levels or sales volumes from different data sources, researchers should be mindful when selecting data and interpreting the results of the analysis.

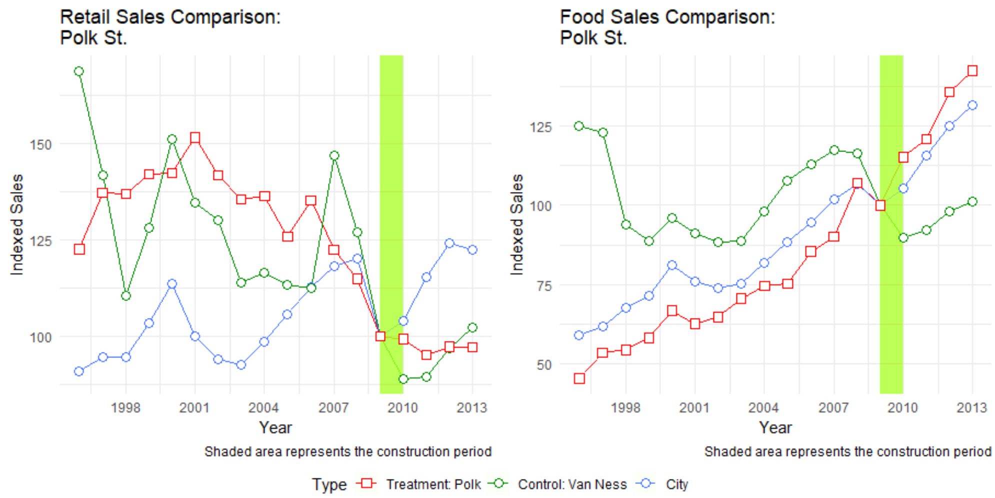
Even with a thorough understanding of the advantages and disadvantages and inclusions and exclusions of each data source, we may still observe disparities in the analysis results. We believe that this underscores the importance of using multiple data sources to validate economic outcomes and trends from street improvements, as well as the importance of understanding the local or regional context when interpreting these quantitative results.

In summary, for employment and estimated sales data with the finest geographical scale, NETS and retail sales tax data would be the most appropriate data sources. However, the tradeoff of utilizing NETS data is that the most recently released data only includes information up to 2015, and sales revenue is an estimated number. In addition, because the NETS data is proprietary and processed by a private firm, it can be cost prohibitive to obtain and comes with its own set of usage limitations (that limit the usage to a certain contractual period). Retail sales tax data and QCEW data can also provide accurate economic indicator data at very fine geographic detail (at the establishment level in some cases), but non-aggregated data is typically confidential and researchers and/or practitioners may not be able to access the disaggregated data needed for analysis. In some cases, it may only be possible to obtain these public datasets in an aggregate format for specified corridors, which may impede the researcher's ability to observe nuances in the data or to further manipulate the data for different types of methodologies. The LEHD data source may be the only public data source that includes economic indicators at this geographic detail. While this data may present challenges at smaller geographic scales (as discussed previously), it serves as a consistent data source for the corridor selection process and to understand approximate economic development trends on the street improvement corridors. Oftentimes, we are required to provide specific corridor or geographic details in our data requests for confidential public data, such as the QCEW or sales tax data, and the ability to conduct preliminary corridor selection using LEHD data is invaluable. Finally, both LEHD and NETS data come in a standardized consistent data format that lessens the need to further process or clean the data, while QCEW and sales tax data from each state or city may be delivered in a variety of formats.

LEHD



Retail Sales



NETS (Type I)

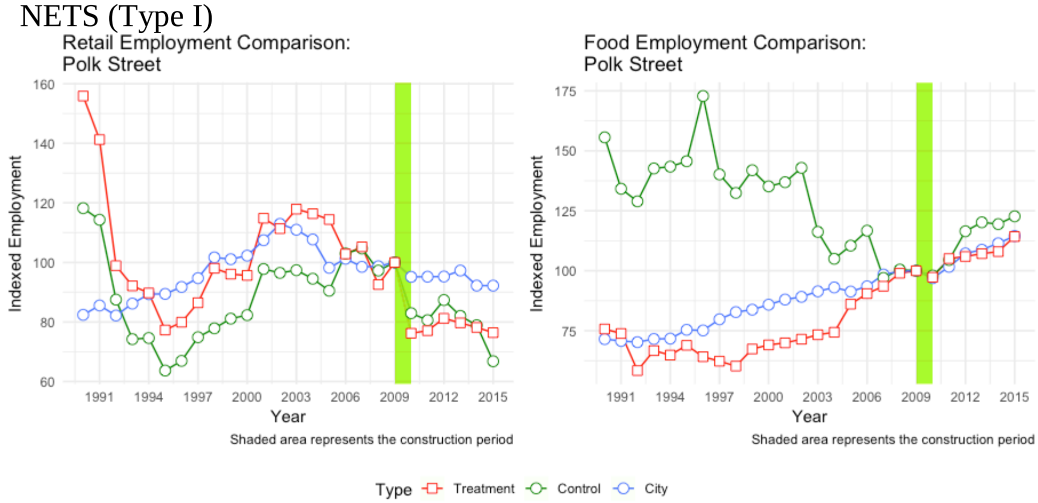
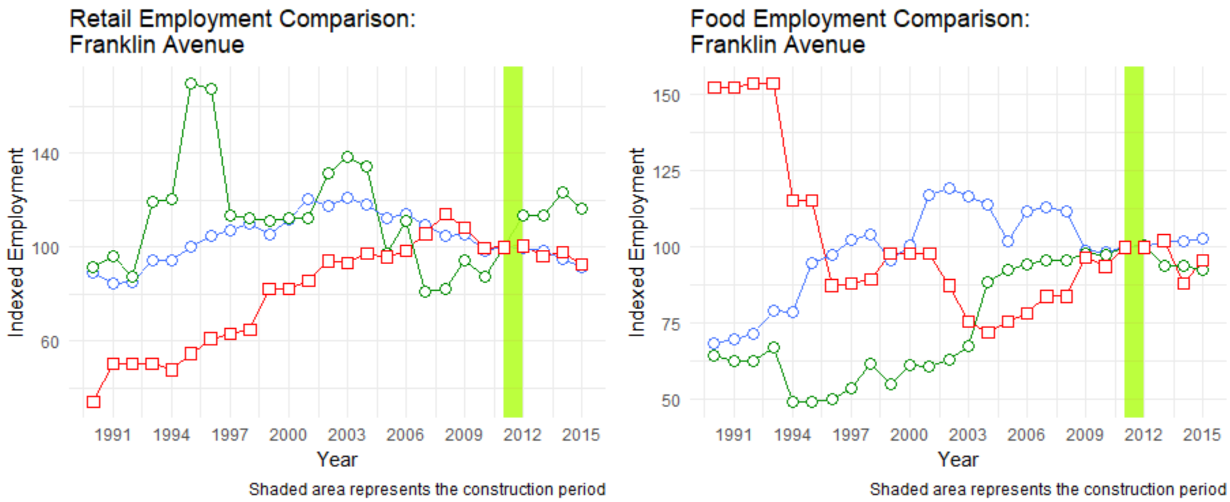


Figure 10-1. Comparison Between LEHD Data With Other Data Sources (Polk Street, San Francisco)

NETS (Type I)



NETS (Type II)

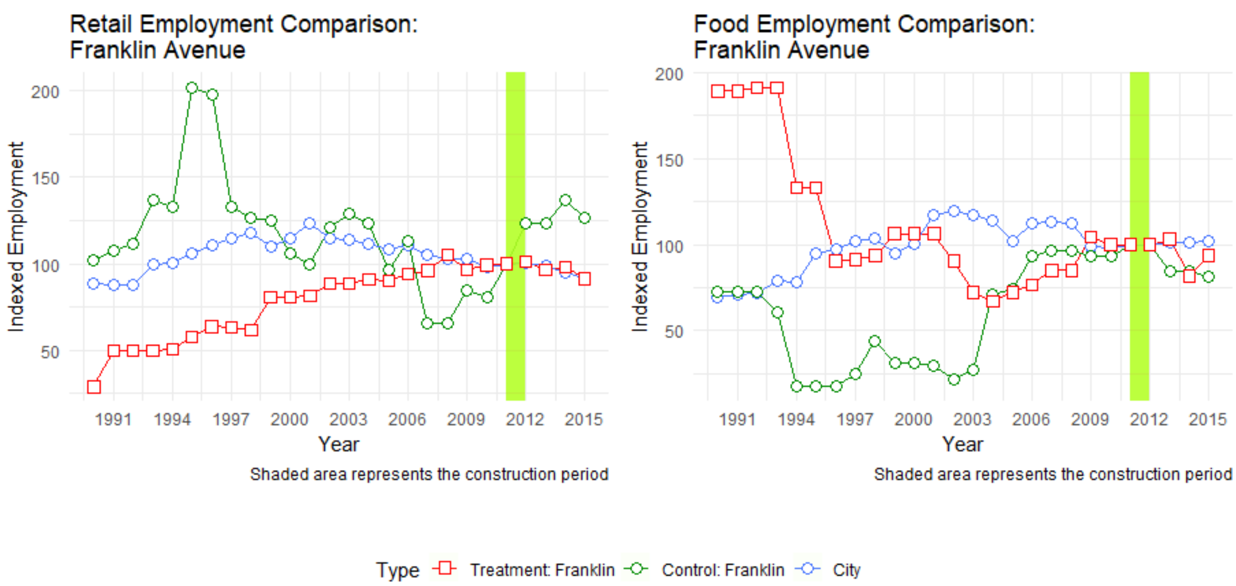
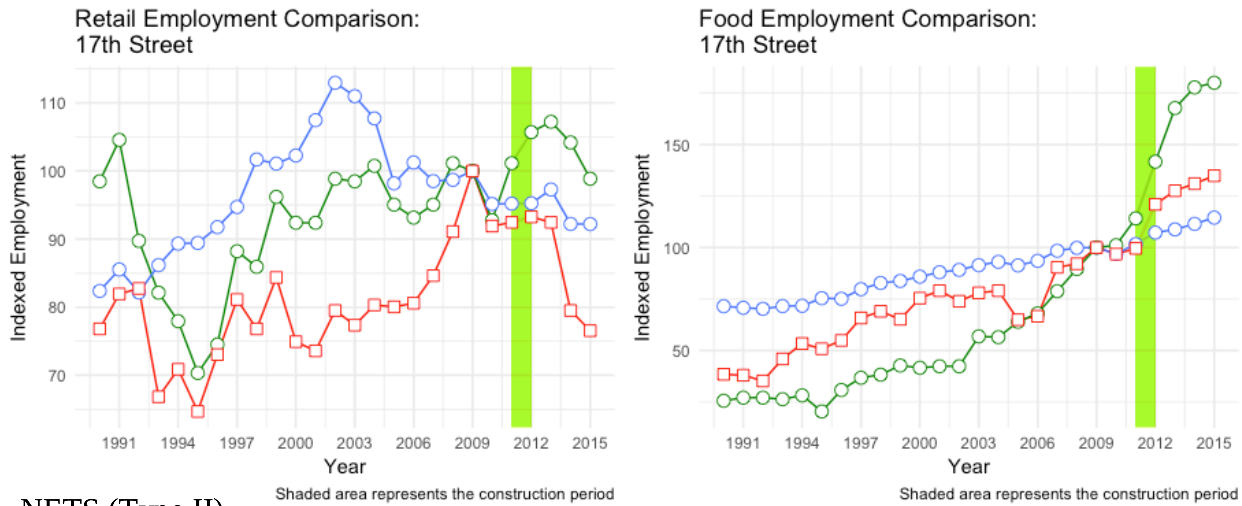


Figure 10-2. Similarity Between Type I and Type II NETS Data (Franklin Ave., Minneapolis)

NETS (Type I)



NETS (Type II)

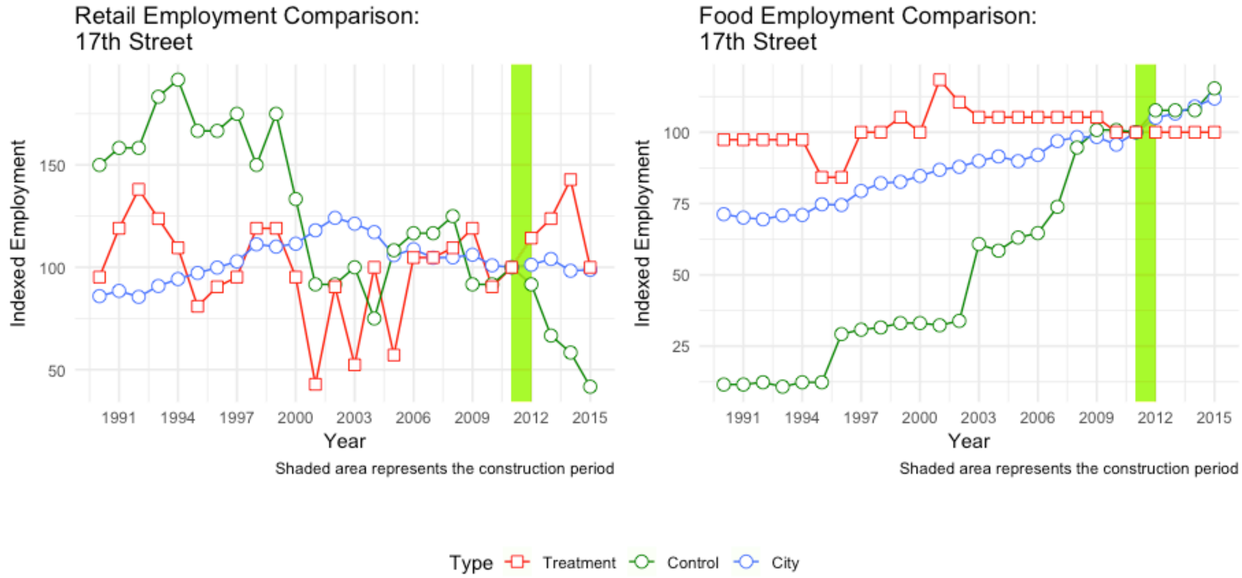


Figure 10-3. Disparity Between Type I and Type II NETS Data (17th Street, San Francisco)

9.2 METHODOLOGY COMPARISON

We proposed three different methodological approaches to investigate the economic impacts on street improvement corridors. Aggregated trend analysis and difference-in-difference (DID) analysis both utilize control corridors to understand the impacts on the treatment corridor, while interrupted time series (ITS) is an econometric technique that analyzes multiple time points on the treatment corridor itself. While the aggregated trend analysis is a visual comparison that examines the differences in trends and growth rates between treatment and control corridors, DID and ITS analyses are quasi-experimental econometric methodologies. Quasi-experimental methodologies such as the DID and ITS analyses provide researchers with the ability to ascertain causality, or whether the street improvements that were constructed on the analysis corridors caused any changes to employment, sales revenue or wages. While these quasi-experimental methods can improve the rigor in this type of analysis, they also come with additional requirements in the quality and quantity of the data, as well as how well the control corridor is matched with the street improvement treatment corridor. One of the major contributions of this research is providing a systematic framework for evaluating the economic development effects of corridor-level bicycle or pedestrian street improvements. Current literature and practice mainly utilize case studies or visual comparisons as the main analysis methods, while this research proposes two relatively straightforward econometric methods, DID and ITS, to increase the validity of the results as long as the data fit the assumptions of the methodology.

In general, we find that the ITS analysis provides more robust results than the other two methods since it is a method that does not utilize control corridors. Although statistical tests were conducted in the corridor selection process to ensure sufficient similarity between treatment and control corridors, many times there may not exist a perfectly matched control corridor for our treatment corridor in reality. In some cases, we contend with treatment and control corridors which are neighboring street corridors. While these neighboring street corridors may be the most similar corridors, because much of the data exists at the block level, we may have overlapping blocks where we may not be able to separate whether employment numbers belong to one corridor or the other. For example, on 17th Street in San Francisco, there was a large increase in food employment on the 18th Street control corridor. DID analysis and aggregated trend analysis, both relying on comparable control corridors, indicate that when compared to the control corridor, the 17th Street treatment corridor did not perform as well economically following the street improvement construction. However, upon further analysis using the ITS approach, we observed that the 17th Street corridor did not experience any significant decreases or increases in economic growth following the bike lane installation, and is following the same growth patterns as before and as the city as a whole.

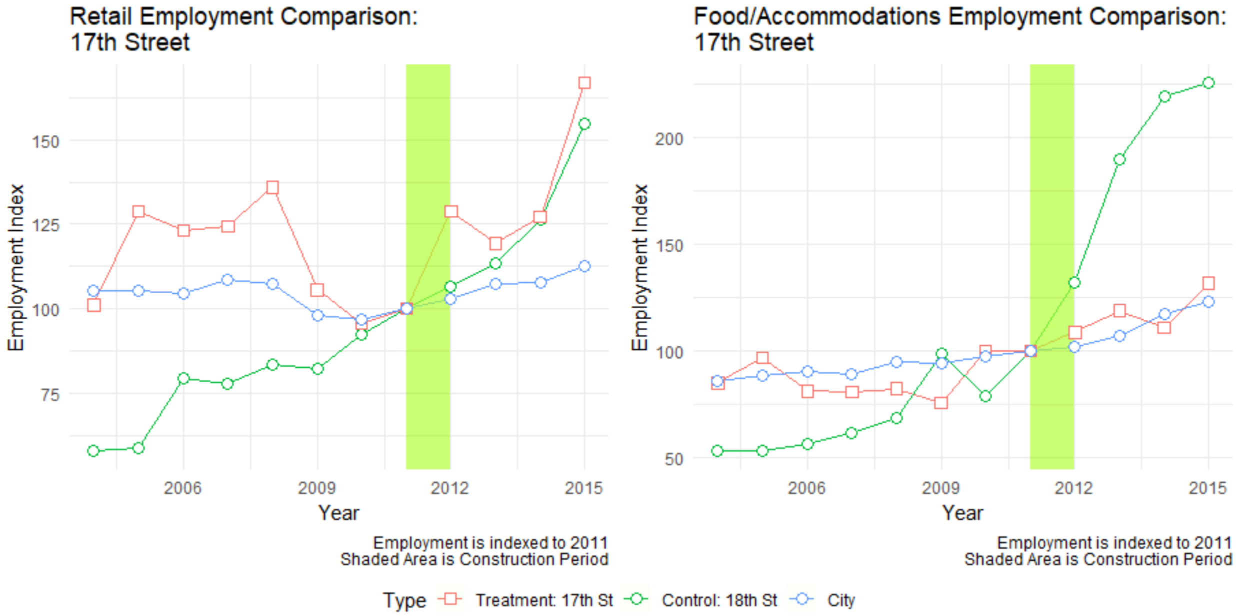


Figure 10-4. Illustration of Control Corridor Issues (17th Street, San Francisco)

In addition to sensitivities associated with selecting an appropriate control corridor, a robust DID analysis also requires additional assumptions for analysis. One important requirement for DID analysis is that the treatment and control corridors should follow a parallel trend prior to the treatment. However, as shown in the left figure of Figure 10-4, the pre-treatment trends are quite different for the 17th Street treatment and 18th Street control corridors. In particular, when the two corridors start out with very different economic indicator levels, the DID analysis may lead to conflicting results than the aggregated trend analysis.

Our research proposes a systematical approach to selecting treatment and control corridors, but the approach still relies heavily on local experts' guidance for candidate/proposed corridors. When the corridors are not perfectly comparable to their treatment counterpart, validity issues in the econometric analysis may arise and lead to biased analytical results. In the future, as the Internet of things becomes more prevalent and bicycling and walking data can be collected on a broader or more automated basis, a completely data-based corridor selection process may become possible. Additional innovative methodologies, such as the synthetic control method (Abadie et al., 2010; Dube et al., 2015) which constructs synthetic combinations of weighted control corridors to perfectly match up with the treatment corridor, may help to solve the issues of control corridor comparability encountered in the aggregated trend or DID analysis.

The ITS analysis approach generally requires more data points post-intervention to achieve meaningful and valid impact estimations. In most of our cases, we find either non-significant estimates, or negative in level change but positive in slope change results. Many of these results may be attributed to the short time period that has passed since the street improvement installation, and additional time series data points may be needed to draw valid conclusions in the future.

There are additional issues that cause the different findings among different approaches besides pure methodology issues.

- Industry shift between retail and food services is observed in some corridors. Take Polk Street in San Francisco as an example; the sales tax data and NETS data both indicate the retail industry declined in the treatment corridor, while the food service industry grew during the same period. Within the context of understanding street improvements for bicycle or pedestrian mobility, we may need to more carefully examine whether certain types of street improvements attract certain types of businesses or consumption behavior than others, leading to industrial shifts along these corridors.
- In some cases, we are able to calculate the number of employment or sales revenue per establishment along street improvement corridors, which may provide additional details that aid in the interpretation of our analysis results. For example, although the overall employment of the Stark and Oak corridor (NETS Type II) in Portland increased significantly, the per establishment employment didn’t change much which could mean that the change in employment is due to the opening of more establishments along that corridor, or the new street improvement may favor a transition towards smaller establishments. However, the Type I data analysis of the Stark and Oak corridor showed decreasing retail employment at the same time as increasing retail sales. The sales revenue per establishment graph indicates the change in overall employment may be caused by a shift in the type of retail stores along this corridor, shifting from more labor-intensive retail stores to high-value sales, low labor-intensity stores.
- Many of the street improvements took place during the economic recession period. Thus, some of the fluctuations in the economic indicators may be directly reflecting the overall economic conditions rather than outcomes that can be attributed to the street improvement construction. While some of these effects are already controlled for with the use of control corridors within the same city in some of our analysis approaches, we recommend that further research be conducted to incorporate additional economic control factors to isolate the impacts of the recessionary period (or other general economic trajectories) from the street improvement installation.

We hope that this discussion highlights the importance of the corridor selection process to justify similarity between treatment and control corridors, and also the importance of examining these types of economic development impacts using multiple data sources and multiple methodology approaches to accurately capture the impacts of street improvement corridors.

10.0 CONCLUSION

In the face of growing concerns over climate change and rising social inequality, active transportation policy is currently experiencing significant growth. While there are positive trends of placing new bicycle infrastructure on street networks, it still garners intense political backlash in some cities, especially opposition from local business owners who are concerned about the revenue reduction due to the installation of new active transportation infrastructure with travel lanes narrowing and parking removal. There is suggestive evidence showing that upgraded active transportation infrastructure can increase the volumes of consumers arriving via an active transportation mode and, ultimately, contribute to greater revenue for business establishments. However, these studies have largely been descriptive, or exploratory, in nature as opposed to incorporating more rigorous quasi-experimental analysis approaches, most likely due to data limitations. This research addresses the above technical gap by estimating business and economic impacts of bicycle street improvements using relatively straightforward econometric methods in a quasi-experimental research design. In particular, different data sources were applied, ranging from public employment and sales tax data to proprietary data sources.

We analyzed seven street improvement corridors in four cities, Portland, San Francisco, Minneapolis and Memphis. Four types of economic data sources were collected for each city if available: LEHD employment data, QCEW employment and wages data, retail sales tax data, and NETS employment and sales data. We applied three analytical approaches, aggregated trend analysis, difference-in-difference (DID), and interrupted time series (ITS) analysis to evaluate the impacts of street improvements on corridor employment and sales. We generally found that street improvements either had positive impacts on corridor employment and sales or non-significant impacts.

The consistency of the analysis results of the four data sources varies by different corridors for many reasons. First, as we mentioned in the data section, LEHD block-level data is fuzzed for confidentiality. Thus, although aggregating LEHD data to the corridor level can address this issue to some extent, some trend fluctuations may be a reflection of this process rather than actual economic changes. Secondly, we evaluated the economic impacts in two industry sectors: retail and food services, which are captured differently with different data sources. The industry classification in LEHD data only includes industry detail at the two-digit NAICS code level while QCEW data, NETS data and retail sales tax data typically contain more industrial detail, which allowed us to refine the data to business establishments that may be more impacted by street improvements. Thirdly, the various data sources provide for different levels of geographical detail. The LEHD data is only available at the block level, which includes all the establishments within the abutting blocks of the corridor; while oftentimes, we were able to refine the data to include only block-facing establishments through geocoding techniques for the other data sources, which may generate a more accurate geographical boundary for the street improvement impacts. Even with a thorough understanding of the advantages and disadvantages and inclusions and exclusions of each data source, we may still observe disparities in the analysis results. We believe that this underscores the importance of using multiple data sources to validate economic outcomes and trends from street improvements, as well as the importance of understanding the local or regional context when interpreting these quantitative results.

Therefore, for employment and estimated sales data with the finest geographical scale, NETS and retail sales tax data would be the most appropriate data sources. However, the tradeoff of utilizing NETS data is that the most recently released data only includes information up to 2015, and sales revenue is an estimated number. Retail sales tax data and QCEW data can also provide accurate economic indicator data at very fine geographic detail (at the establishment level in some cases), and non-aggregated data is typically confidential and researchers and/or practitioners may need to go through a lengthy process to access the disaggregated data needed for analysis. The LEHD data source may be the only public data source that includes economic indicators at this geographic detail. While this data may present challenges at smaller geographic scales (as discussed previously), it serves as a consistent data source for the corridor selection process and to understand approximate economic development trends on the street improvement corridors.

We proposed three different methodological approaches to investigate the economic impacts on street improvement corridors. Aggregated trend analysis and difference-in-difference (DID) analysis both utilize control corridors to understand the impacts on the treatment corridor, while interrupted time series (ITS) is an econometric technique that analyzes multiple time points on the treatment corridor itself. While the aggregated trend analysis is a visual comparison that examines the differences in trends and growth rates between treatment and control corridors, DID and ITS analyses are quasi-experimental econometric methodologies that allow the researcher to ascertain causality, or whether the street improvements that were constructed on the analysis corridors caused any changes to employment, sales revenue or wages. While these quasi-experimental methods can improve the rigor in this type of analysis, they also come with additional requirements in the quality and quantity of the data, as well as how well the control corridor is matched with the street improvement treatment corridor.

One of the major contributions of this research is to provide a systematic framework for evaluating the economic development effects of corridor-level bicycle or pedestrian street improvements.

In general, we find that the ITS analysis provides more robust results than the other two methods, since it is a method that does not utilize control corridors. However, this approach generally requires more data points post-intervention to achieve meaningful and valid impact estimations. Many of the non-significant results may be attributed to the short time period that has passed since the street improvement installation, and additional time series data points may be needed to draw valid conclusions in the future.

For DID analysis, when the control corridors are not perfectly comparable to their treatment counterparts, validity issues in the econometric analysis may arise and lead to biased analytical results. Although statistical tests were conducted in the corridor selection process to ensure sufficient similarity between treatment and control corridors, many times there may not exist a perfectly matched control corridor for our treatment corridor in reality. In the future, as the internet of things becomes more prevalent and bicycling and walking data can be collected on a broader or more automated basis, a completely data-based corridor selection process may become possible. Additional innovative methodologies, such as the synthetic control method (Abadie et al., 2010; Dube et al., 2015) which constructs synthetic combinations of weighted control corridors to perfectly match up with the treatment corridor, may help to solve the issues of control corridor comparability encountered in the aggregated trend or DID analysis.

Finally, many of the street improvements took place during the economic recession period. Thus, some of the fluctuations in the economic indicators may be directly reflecting the overall economic conditions rather than outcomes that can be attributed to the street improvement construction. While some of these effects are already controlled for with the usage of control corridors within the same city in some of our analysis approaches, we recommend that further research be conducted to incorporate additional economic control factors to isolate the impacts of the recessionary period (or other general economic trajectories) from the street improvement installation.

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